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JUNE, 1923

A WORKING MODEL OF THE TIDES

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A NUMBER of years ago when Dr. Isaiah Bowman, now director of the American Geographical Society of New York, was one of my students, he made under my supervision a working model of the tides, which ought to have been described at that time, and which, as the real tides are still running, deserves description even at this delayed date. The model consisted of a zinc-lined box, about 5 feet square and 10 inches deep, along one side of which the border of a continent was built up of clay and cement with a relief of 6 or 8 inches, so that an ocean, occupying the rest of the box to a depth of 5 or 6 inches, might lap upon the continental slope and mark its shore line. Hanging from springs and dipping into the ocean on the side of the box opposite the continent was a piece of plank which we called the plunger; by raising and lowering it slowly in a 5- or 10-second period as desired, undulations were produced which ran across the ocean and impinged like tide-waves[1] upon the continent, where, on being modified by the varied configuration of the shore line, they imitated a variety of tidal phenomena. The imitation was not a mere analogy but a true homology, for the tides are in reality nothing but a series of waves of small vertical range, of large length from crest to crest, and of 12 hour 26 minute period, which run ashore from whatever part of the ocean their source may lie in.[2] In the open ocean their vertical range is unknown, but it must be small; the range is increased as the waves run from a deep ocean into the shoaling water of a continental margin, and the form of the magnified waves is

[1] The term, tide-wave, is used here in order to avoid confusion with the term, tidal wave, which has unfortunately come to be applied to earthquake waves.

[2] See "Illustrations of tides by waves," *Journal of Geography*, iv, 1905, 290-294.

then further modified according to the pattern of the shore line. All these features were nicely imitated in the working model.

The configuration of the modelled continental margin and its embayments is roughly shown in the accompanying figure, in which the submarine contour lines have vertical intervals of about half an inch, which may be taken to represent several hundred feet in the real ocean. An inch in the diagram represents about a foot in the model, and 20 or 30 miles on a continent. No attempt was made to give the land surface a reasonable form; the pattern of the shore line was the important factor. Short threads or floats, attached to the bottom, serve to show the tidal currents; the tidal rise and fall can be measured on vertical gages divided into inches and fractions, and set up at various points as needed. A long stretch of simple outer shore line, ABC, trending somewhat obliquely to the approach of the open-ocean tide-waves, allows the tide to pass along it in the order of the letters. Attention should be first given to the tide on such an outer shore line because it there exhibits some of the most characteristic, and at the same

DIAGRAM OF A CONTINENTAL BORDER FOR A TIDE MODEL. Scale, about an inch to a foot. Submarine contour interval, about one half inch.

time some of the least generally understood tidal phenomena; namely, the occurrence of high water not at the end of the run of the flood current, but at about the middle of that run, when it has the greatest velocity; and conversely, the occurrence of low water at about the middle of the run of the ebb current, and at the time of its greatest velocity; while rising slack water occurs at about half height between low and high water, when ebb changes to flood; and falling slack water at about half height between high and low water, when flood changes to ebb. Such is the normal relation of these tidal elements.

If the rise and fall of the plunger be so adjusted that the vertical range of tide upon this simple stretch of the outer shore is half an inch, the horizontal range of the alternating flood and ebb currents may well be as much as 2 or 3 inches. Any one who sees this combination of vertical and horizontal movements and realizes that, when combined, they produce an orbital movement in the water, will be prepared to understand the relation of the vertical and horizontal movements of the actual tides on a simple outer shore line. The orbits will be perceived to be long flat ovals, in which the flood current is the forward movement in the upper half of the oval, and the ebb current is the backward movement in the lower half. Evidently, high water, which is produced by the rise of the water to the top of its orbit curve, must be at the middle of the run of the flood; and low water must similarly be at the middle of the run of the ebb. In actual tides on an outer shore line, the vertical range may be only a few feet, while the horizontal range, that is, the run of the flood and the ebb currents, may be almost as many miles. Hence in the orbital movement of the ocean water where a tide passes along a simple outer shore line, the horizontal diameter of the orbit may be several thousand times as great as the vertical diameter.

No one who learns this feature of the tides—and it is, as above stated, one of the most characteristic features of the tides on an outer shore line—will fail to understand that flood and ebb currents are just as essential tidal phenomena as, and indeed are much larger phenomena than rising and falling water. And no one who learns this feature from its simple exposition in a working model will have any trouble in understanding that, on an outer shore line of simple pattern, the rise of the tide from low water to high water takes place during the last half of the ebb and the first half of the flood; and likewise that the fall of the tide from high water to low water takes place during the last half of the flood and the first half of the ebb.

The manner in which these currents combine in order to produce changes of ocean level may be understood after one observes that high water does not occur at the same time all along the continental margin. If the stretch of the outer shore line, ABC, be made long enough to exhibit a high tide at C when the next following low tide is at A and the intermediate falling slack water is at B, attentive observation will disclose the explanatory fact that at the moment when the tides are so disposed, the water between B and C is moving, as part of a flood current, toward C; while the water between B and A is moving at the same moment, as part of an ebb current, toward A. Hence as the water on either side of the slack point, B, is moving away from that point, the water at the slack point must be falling, in preparation for the low-water phase of the tide-wave which will soon arrive there. On the other hand, when a high-water phase is at A and a low-water phase is at C, the water is moving toward B from either side, and hence the slack water there must be rising in preparation for the arrival of the next high-water phase.

A long, narrow and shoaling bay, DEF, indents the continental coast. It may represent such actual indentations as Delaware and Chesapeake bays. The high-tide wave may be watched as it enters the bay and runs up it; and one may then note that high water occurs later and later at points farther and farther inland, that the rate of advance of high water up the bay becomes slower and slower as it advances into shallower and shallower water, and that the vertical range of the tide, perhaps increasing at first, then decreases to smaller and smaller measures as the bay head is approached. With the slower advance of high water in the bay, the distance from one high water to another, that is, the length of the tide-wave, diminishes. One may also discover that in this bay the relation of the flood and ebb currents to high and low water and to the two slack waters gradually departs from the normal relation which they held on the outer coast, ABC, until, directly at the closed head of the bay, the slack waters coincide with high and low water, the flood current runs up from low water to high water, and the ebb current runs down from high water to low water. Such is the special relation of these tidal elements at bay heads.

By constructing shoals of various depths and breadths along the bay sides, the unlike dimensions of tidal flats for tides of similar range may be exhibited. By opening a shallow, half-tide embayment on one side of the main bay, as at F, a minutely rippling rush of rising tide will advance over it, like that which takes place on a vastly larger scale in the Bay of Mont St. Michel on the

northwestern coast of France. If the main bay be long enough, the tides may be reduced to a hardly perceptible range at its distant head. If, instead of being closed at its head, the bay there receives a river, GE, down which a gentle current of water runs from a faucet at G—a compensating outflow being provided in an escape pipe at one end of the ocean—the combination of river current running down-valley and of the tidal wave running up-valley may be examined. Experiment is here needed to determine a satisfactory relation of river current and tidal oscillation.

A small bay, H, will exhibit very clearly at its inner end the special bay-head relation of rising and falling tide and flood and ebb currents just described for the larger bay, DF, where that relation will not be well shown if a good-sized river, GE, opens into the bay head. Tidal currents will be relatively weak in the small bay, and must be inconspicuous at its head. It is presumably because most persons who look casually at the tides see them at or near bay heads that the special relation there obtaining between the rise and fall of the tide and the weakened run of the flood and ebb currents has come to be regarded as the normal and general relation; but in reality the normal relation is, as explained above, that exhibited on the outer shore line, ABC. It is, furthermore, very likely because harbor tides are ordinarily seen by casual observers that the vertical change of level has come to outrank the horizontal currents in the popular estimation of tidal phenomena. To be sure, change of water level and hence change of depth in harbors gives the vertical range there a practical importance in navigation which greatly exceeds the leisurely run of the tidal currents in such situations; but in coastwise navigation a little way off shore, where depth is sufficient even at low tide, the run of the currents is more significant than the tidal rise and fall. For example, as schooners can not sail very close to the wind they may find it necessary to anchor if wind and tidal currents are both unfavorable and wait until the current slacks and changes; then, with the current in their favor, beating against the wind is possible. I have seen a fleet of over 70 east-bound schooners thus lying at anchor in Nantucket sound while the wind and current were both against them; but as soon as the current changed, they all heaved anchor and set sail, making their way eastward around Monomoy point against the wind and then as fast as possible northward along the harborless outer side or "back" of Cape Cod.

If the small bay, H, be of appropriate configuration, the tide may increase slightly toward its head, instead of diminishing as at the head of the long bay, DE. And if a bay have a configuration

like a pouch or funnel, well opened and fairly deep at the mouth, as in bay J, the swashing oscillation of a standing wave, instead of the undulation of an advancing wave, may be produced in it. Such an oscillation will have an exaggerated vertical range at the head of the bay, as is the case in the Bay of Fundy. In a standing wave of this kind, it should be noted that high water is not much more delayed at the head than at the mouth of the bay, but occurs almost simultaneously all along the bay length. If the exaggerated high tide at the bay head enters a river, K, it will produce a tidal bore, or rushing wave of translation, rolling over and foaming at its front as it hurries up the river channel and rapidly fills it to high-tide level.[3] The fall to low tide is more gradual. Hence a river bore causes high water to occur nearer to the preceding than to the following low water.

Another bay, M, of moderate size, constricted at its mouth by sand reefs between which only a narrow inlet remains open, will have a reduced range of tide as compared with the adjoining outer shore line or with neighboring open bays; but it will have also greatly accelerated tidal currents rushing alternately in and out through the narrow inlet, in their unsuccessful effort to give the bay as great a tidal range as that outside. The trouble is that they have not time, in the short period of the tides, to do what they try to do. It may be noted that, if a bay of this kind still bears around its shore the marks of high-water wave work done before the sand reefs enclosed the bay mouth, such marks must stand somewhat higher than the diminished reach of high water since the enclosure of the bay; and an observer on discovering this discrepancy and not understanding its origin might conclude that a slight elevation of the land had recently taken place there. But if the observer be acquainted with Johnson's principle regarding the relation of the changes in shore lines made by waves and tides to the changes imposed on the tides by the changing shore lines, he will perceive that the discrepancy between the former and the present reach of high tide in the bay is not the result of an elevation of the land, but simply, as above intimated, of a local reduction of tidal range in the bay by reason of the formation of sand reefs across the bay mouth.

By adding a small bay, L, with a narrow entrance, at the side of the pouch bay, J, and making the bottom of the side-bay entrance about at half-tide level, the in-and-out currents there re-

3 Good pictures showing the great range of tide in the Bay of Fundy and of the bore in the Peticodiac River, which enters the bay at its head, are given in the *National Geographical Magazine* for February, 1905.

sulting from the strong rise and fall of the tide in the pouch bay, will act like a reversing cascade, such as occurs on a rocky ledge at the entrance to the harbor of St. John, New Brunswick. Finally, a long river, N, may exhibit more clearly than the shorter river, GE, the interaction of river and tidal currents, the diminution of tide-wave length, and the gradual extinction of the tide up stream. If the river be long enough, two or more high tides may be seen advancing up it at the same time. If the mouth of such a river is somewhat funnel-shaped, the entering tide may take the form of a moderate bore, but less pronounced than that produced where the pouch bay, J, leads up to the river, K.

It has been tacitly assumed thus far that the beds of the rivers, GE, K and N, lie a little below mean sea level so far as they are included in the model; in that case the "head of tide" will not be distinctly marked. Let the bed of river, N, therefore, have a slightly increased slope, so that it rises above sea level about three quarters way up stream from its mouth to the model side. A well-defined contrast will then appear between the slender stream, which is fed from a faucet at the margin of the model and which runs in a trickling current down the upper quarter of the channel as a true river, and the much larger water course which, backed up from the ocean, occupies the lower three quarters of the channel and sways back and forth with the tides. Many of our Atlantic rivers exhibit this marked change of size at the head of tide. Down stream from that point the river becomes an estuary. Although the volume of water discharged from such an estuary to the ocean is little more than that received by the estuary from the true river at head of tide, the volume of water moved in the tidal currents of the estuary is immensely greater than the river discharge.

One thing more: when the tide-waves are working on the outer shore and in all the bays and rivers, it should be noted that, however much they are changed in wave length, in rate of progress, in range and in force, their period, that is, the time between the passage of two high tides at a given point, remains unchanged: it is everywhere the same.

Nearly all the tidal phenomena here described were well illustrated in our working model, but some of our efforts were not wholly successful. For example, we tried to construct an island in the large bay of such form and dimensions as to admit a tide-wave around each of its ends, so that there should be a point behind the island where the two tide waves, travelling unlike distances, would arrive with opposite phases and thus neutralize each other, producing a no-tide node of unchanging level. Such a no-

tide node was predicted by Whewell for the North Sea and afterwards discovered at a point where two tidal waves, one entering by the Straits of Dover on the south and the other coming around Scotland on the north, meet and counterbalance each other. There is little question that, had our experiments been continued a little longer, a no-tide point could have been produced. Another tidal feature that we wished to illustrate but did not realize is that of accelerated currents in a strait, like Hell-gate between New York harbor and Long Island sound. In this case a tide-wave arriving from one extremity of a long island produces high water at one end of a short strait when the corresponding tide-wave arriving from the other extremity of the long island produces low water at the other end of the strait: a strong gradient is thus produced in the strait and as a consequence the water rushes through it, first one way, then the other, whirling and eddying as it goes. The original whirling currents of Hell-gate have been greatly diminished by blasting away the rock ledges that formerly obstructed the channel.

There is another manifestly possible development of the model that we did not attempt; that is, a combination of two plungers driven by clock-work with slightly different periods and ranges, so that the one of longer period and greater range makes 13 oscillations while the one of shorter period and smaller range makes 14 oscillations, thus illustrating the luni-solar tides. If the plungers were hidden behind a curtain or screen, it would be an interesting problem for an attentive observer to determine the periods and ranges of the tide tide-making forces by studying the variations of the little tides on the imitation continental shores. Whether it would be worth while to complicate the movements of the plungers still further so as to exhibit the diurnal inequality of the tides must be left to some willing experimenter.

What the real and lasting value of a working model of this kind may be remains to be determined. Perhaps it will have to be included in that long list of laboratory devices which one teacher uses and which his successor discards.[4] Indeed, our tidal model was merely an example of those contraptions which one and the same teacher uses for a time and then abandons, because of lack of time or because of redistribution of emphasis in the course of his teaching; for that was the fate of the model above described. But if a working model of this kind were made for the gallery of a public museum, and on so large a scale that the ocean area should

[4] It is to be feared that this fate has overtaken a number of the pieces of geological apparatus recently reported to H. F. Cleland from various laboratories and described in his article, "Demonstration material in geology," *Bull. Geol. Soc. Amer.*, xxxiii, 1922, 56-85.

have a width of some 10 feet and the continental border a length of 15 or 20 feet, it would surely attract the attention of many visitors, if for no other reasons than that it would be a going concern. The movement of its floats and current-threads and the rise and fall of the water surface on its graduated gages would stop the casual visitor, and after stopping, he might really look closely to see what is going on. The plunger that actuates the tide waves should be concealed, as it would otherwise take too much of an observer's attention. It is said that the number of visitors to a museum of mechanical models in London was greatly increased when, from being merely stationary exhibits, they were made to "go."

But if a working tidal model is set up in a museum, one thing is certain; it ought to have a series of what are known as question-labels set up around it, by which an observant visitor shall be led to find out for himself the nature of the phenomena that the model illustrates. If only a mere name-label were on such a model, it would have very little value. How often, indeed, does one see visitors in a museum look at a name-label, and upon thus learning the most artificial part of the exhibit, walk away with hardly a glance at the thing that is named! Let me emphasize this point by the case of a museum exhibit of a group of anthropoid skeletons.

Below each of the skeletons in such an exhibit one ordinarily sees a name-label; a scientific name, to be sure, but nothing more. Yet each skeleton shows many more facts than its name; and the facts about the skeletons are best learned by observation, not by reading name-labels. It may be said, of course, that the skeletons are in plain sight, directly before the visitor; and that if the visitor wishes to see what the skeletons are, he has only to look at them. But this overlooks the patent fact that most visitors to museums do not know how to look at the exhibits; and that, even if they look, they do not really see much of what they look at. Thousands of visitors pass groups of anthropoid skeletons in various museums, and hardly one in a thousand of them consciously sees the extraordinary facts which the skeletons expose. Would it not therefore be worth while to attach to such exhibits a few question-labels, running somewhat as follows:

Does any one of these skeletons possess a bone that is not represented by a similar bone in all the other skeletons?

Which skeleton has the heaviest or the lightest bones in proportion to its size?

Which skeleton has the largest bone surfaces for the attachment of muscles?

Which skeleton therefore seems to represent the strongest being?

Are the skeletons arranged in order of inferred strength?

In which skeleton are the arms of greatest or of least length in proportion to height?

If the arms were straight and the skeletons were erect, how far down the legs would the finger tips reach in each of them?

Are the skeletons arranged in order of relative arm length?

In which skeleton does the arrangement of the big toe bones in the foot most nearly resemble that of the thumb bones in the hand?

What differences in habits of walking and climbing do these differences of bone arrangement suggest?

In which skeleton does the profile from the top of the head to the mouth, as seen from one side, slant at the lowest or the highest angle?

In which skeleton is the chin most retreating, most square, most pointed?

Compare the angle between the forehead profile and the chin profile in the different skeletons.

Are the skeletons arranged in order of forehead-chin angle?

In which skeleton does the skull appear to afford the least or the greatest space for the brain in proportion to the total size of the skeleton?

Are the skeletons arranged in order of relative brain space?

Which skeleton probably represents the least intelligent or the most intelligent being?

What animals and what races of mankind are represented by the skeletons?

The essential feature of these questions is that they direct attention to significant facts which are as a rule overlooked by undirected attention, and which are nevertheless easily discovered by conscious attention. And it is to be remarked that not until these significant facts have been discovered by observation should the name-labels of the skeletons be referred to. The names may then serve their proper purpose of verbal handles with which to pick up packages of observed facts, instead of serving, as too often happens, the improper purpose of masks which discourage or even impede the observation of the facts. With such question-labels as aids, a group of anthropoid skeletons or any other similar exhibit in a museum might be looked at intelligently by perhaps 30 or 40 visitors in a thousand; and at least those 30 or 40 would then carry away an instructive mental impression regarding a certain number of definite things, instead of only a confused and vague memory of a vast number of half-seen or less-seen things.

A working model of the tides in a museum should likewise have a carefully prepared series of question-labels around it. The questions might be graded to advantage; some being of an elementary nature, adapted to school children; others being more advanced, adapted to adults. Experiment as to the usefulness of the question-labels could be made by showing them and removing them in alternate months, and comparing the attention given to the model with and without their aid. Some sample questions for adults are here suggested:

What is the time interval between the moments of successive high waters at A or B or C? (Note. This can be best determined by measuring the total time of ten or more high-water intervals, and then dividing the time by the number).

What is the change of water level or vertical range between low water and high water at A or B or C? (This may be measured on vertical gages a little off shore, on which inches and fractions are marked).

Describe the horizontal movements of the water, or tidal currents, associated with changes of water level at A or B or C. (The currents may be shown by little moored floats or by threads attached to the bottom a little off shore).

How far does the water move in these alternating tidal currents? (Scales of inches and fractions should be marked along the shore at various points).

What is the average velocity of each current?

At what time in the run of each current is its velocity greatest?

Estimate the velocity at that time and compare this greatest velocity with the average velocity.

Describe the relation of the alternating horizontal currents to the rise and fall of the water surface. (Note. The current that is running at the time of high water is called the flood or flood tide; at the time of low water, the ebb or ebb tide. The brief time when the currents cease running in order to change direction is called slack water).

What is the relation of rising slack water to ebb and flood?

Answer the same question for falling slack water.

* * * * * * * * *

(The progressive advance of successive tide-waves or high water up the large bay, DE, having been brought out by appropriate questions): How much later is high water at the head of the bay than at its entrance?

What is the average velocity of high-water advance up the bay?

Compare this velocity with that of the tide-wave crest as it crosses the open ocean. (Note. Several vertical gages, divided into inches and fractions near the water surface, should be set up in a line across the ocean to show its changes of surface level as the tide-wave advances).

* * * * * * * * *

(Appropriate questions having been asked as to the range of tide at the mouth and head of the pouch bay, J.): Compare the time of high water at the mouth and the head of the bay.

Compare the movement of the water in this pouch bay with that in bays DE and H.

* * * * * * * * *

(In case a double plunger is constructed to show the luni-solar tides): Observe 30 or 40 successive high waters at A or B or C. How much does their range vary?

In how many tidal periods is the variation of range accomplished?

Assuming that the stronger tides result from the added action of two periodic tide-producing forces, and that the weaker tides result from their opposed action, what is the relative value of the two forces? What is the period of each force?

These sample questions suffice to show that a great variety of instructive exercises upon the facts shown by the tide model may

be provided. But they show also, as in the case of the anthropoid skeletons, that the exercises can be properly solved only by a painstaking observer; and that even such an observer will lose much time unless he is guided by the question-labels. It is of course true that few visitors to a public museum will care to give the time, or will have the time to give, that is demanded for the plodding progress along the true plebeian road to such learning as is here afforded; but those few will be repaid for their patience and persistence.

It was, indeed, with the object of using our working tide model in teaching the tides that it was first constructed in the basement below my laboratory by Dr. Bowman, as intimated above; but the practical difficulties of carrying out an informing and disciplinary exercise on the model, in systematic association with the routine of class and laboratory work, proved difficult and discouraging. The model could not be exhibited during a lecture, partly because of the small dimensions of its phenomena, still more because its level water surface could not be seen by an audience of seated students. Only a few students could examine the model at the same time even in the laboratory; hence in a class of 80 or 100 members, 10 or 15 sections would have had to take their turn, and each section would have needed at least half an hour—better, an hour—to solve the assigned questions. The labor of arranging the times at which so many sections could examine the model appeared to be greater than the profit they could get from it. Yet it has always been a regret that such observational work on the model could not have been introduced as a regular part of laboratory exercises while the lectures on tides were in progress; for the model would then have provided a basis of fact, even though only imitative fact, on which the theory of the tides could have been expounded. Perhaps some more energetic teacher may accomplish this desired result.

But in spite of the difficulties in the way of making practical use of the working tide model in teaching, such a working model may still have a high value as a museum exhibit; and this article is written chiefly in the hope that it may encourage museum directors to try the experiment of constructing a tide model and running it by clock work, so that it shall always be going and ready for examination by such visitors as care to examine it. Let it be remembered, however, that a series of question-labels is just about as important as the periodic plunger in bringing the model up to its real value as an instructive scientific exhibit. A working model of this kind, in the presence of which the should-be

observer remains passive, is hardly worth its cost or worthy of its space. Its value will not lie in the work that it does, but in the work that the museum visitor does upon it; and as such work should be of a thoughtful and systematic and disciplinary kind, its performance is not to be expected without the aid of question-label guides. It is my belief that if museums had many exhibits such as groups of anthropoid skeletons or working tide models, each with appropriate question-labels, the public would gain more instruction from them than is now the case.

DISEASE AND HEREDITY

By Professor LEO LOEB
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AT the present time there is a widespread interest in all problems which relate to heredity, and the ramifications of these problems extend into very diverse fields of social as well as individual life. Yet it is only a relatively short time since the public in general became acquainted with the question of heredity, the first impetus in this direction being due perhaps, more than anything else, to the influence of a modern writer, Henrik Ibsen, who very powerfully, although from a scientific point of view incorrectly, first presented on the stage the tragic consequences of the heredity of disease.

In any discussion of this subject, it is essential first to have an understanding of the meaning of the terms "disease" and "heredity." To define heredity, we must go back to the carriers of heredity; and these are the germ cells—the egg in the case of the mother, the spermatozoon in the case of the father. Both of these cells contain what is called the germ plasm, which really constitutes the sum of all hereditary factors. The germ cells, after having united, or, expressed in a different manner, after fertilization has taken place, develop into the embryo and in the full grown individual, and the character of the germ plasm, which partly comes from the mother and partly from the father, determines what kind of an embryo and what kind of an individual shall be produced. At an early stage of development the fertilized germ cells give origin in the embryo to new germ cells, which later become the germ cells of the individual—egg in the female, spermatozoon in the male. Thus in successive generations the germ cells form one continuous series, the united parent germ cells giving rise to a next generation of germ cells in the offspring; and because one generation of germ cells is derived directly from the preceding generation, therefore the germ plasm, of which the germ cells are the depository, is transmitted continuously from generation to generation. It is this continuity of the germ plasm through endless generations which is the basis and cause of heredity in living organisms, plants, animals and man.

Now we have said that an individual has the same structure

and functions as the parents, because in so far as the germ plasm is the same in both; but while this statement taken in a broad way is correct, it needs in reality certain modifications. The character of the germ plasm is indeed the main factor which determines the structure and functions of the fully developed organism, but the germ cells themselves need for the display of their power the constant interaction with environmental factors. These latter may be situated within the developing individual, when they represent an inner environment; or they may be situated in the outer world and then they represent an outer environment. The environmental factors include the common conditions upon which our life depends, such as light, heat, oxygen and foodstuffs; but there are also specific environmental factors which the germ plasm needs in order to be able to produce specific structures and specific functions. Some of these environmental factors can be varied and sometimes even eliminated experimentally without endangering the life of the individual as a whole, while others are relatively constant and unchangeable and necessary, if life and development are to proceed. It is well to insist upon this interaction of germ plasm and environment in order to understand the significance and the limitations of heredity in disease. If the germ plasm is normal and if the environmental factors are normal, a healthy organism results. But if the germ plasm, which in reality is made up of a multitude of individual units, if this germ plasm or the environmental factors are abnormal, then disease results.

We spoke just now of the germ plasm of an organism as being composed of a multitude of individual units. Part of these were passed on to the offspring from the father, part from the mother, and their combination determines how far the individual resembles the father and how far it resembles the mother. But there may be in the offspring characters which have not been visible in either of the parents, because in the latter they had been hidden. Such factors, hidden in the parents, but appearing in the offspring, are called recessive unit factors, and for a recessive factor to become manifest in the child it is necessary that both parents carry it latent in their germ cells and that it thus be present in double dose in the child. On the other hand, it is possible for a unit factor to become manifest in the offspring, although it has been received from only one parent, as this factor tends to dominate, as far as manifestation is concerned, over the parallel unit factor in the other parent, and such factors are called dominant unit factors. Thus, for instance, a dark eye-color as a rule dominates over the blue eye-color. Sometimes unit factors, and in particular some of those which determine certain diseases, are

coupled with other unit factors which determine whether the offspring shall be a male or a female. In this case a disease may appear, for instance, only in the male members of a certain family; yet it is transmitted by the females, although in the latter it is not manifest, because the unit factor or factors upon which the disease depends is recessive. Such a disease would be due to what is called the sex-linked recessive type of heredity.

From what has been said, we may easily reason out that as far as heredity is concerned there are three possible classes of diseases: (1) In the first place, the germ plasm of an individual may be normal and therefore have a satisfactory hereditary endowment, but certain injurious influences attack him from without, and cause either directly or indirectly a disturbance in the structure, composition and functioning of the organism. Such injuries might, for instance, be due to the action of excessive heat or cold, to the absorption of certain poisons or to the entrance of microorganisms. Diseases thus produced are entirely the result of environmental factors. (2) There is a second class of diseases which result from an altered constitution of the germ plasm. These are necessarily of a hereditary character because, as we have seen, the germ plasm is transmitted from generation to generation. But as the germ plasm interacts always with certain environmental factors, strictly speaking the latter enter also this class of diseases as a component cause. However, then, environmental factors are common needs in life processes in general, they are constant and fixed and are not susceptible of alteration, and they are, therefore, not really causes of such diseases in the sense in which heredity is the cause. (3) In the third class of diseases also the germ plasm is altered in an injurious direction; but in this case the change is of a more delicate nature and it requires, in order to become manifest as disease, the cooperation of certain environmental factors, which are variable; they can be diminished or increased or may be entirely eliminated and the disease varies in a parellel manner. In certain cases an individual with an injured or somewhat abnormal germ plasm may be practically normal under a healthy environment, but if a surplus or a deficiency of environmental factors, which in a person with a healthy germ plasm would be without injurious consequences, should affect them. disease would result. In this third class, then, we have to deal with diseases in which both germ plasm and environment enter, but in each disease the alterations of the germ plasm and the character of the environmental factors, which are responsible for the disease, vary.

It follows thus that in order to define the significance of heredity

in a given disease, we have to answer three questions: (1) Is the disease due to environmental factors, or to changes in the germ plasm, or to both these factors? (2) If both factors enter, how much is due to each, and what are the environmental factors which come into play? (3) If heredity plays a part, wherein does the change in the germ plasm consist and what is the character of the hereditary transmission? Are the disease-producing factors recessive or dominant? Are they sex-linked or do multiple factors underlie the condition? Now, at the present time our knowledge is not complete enough to answer all these sets of questions; the character of the hereditary transmission and the changes in the germ plasm leading to disease in particular are doubtful in many cases, owing to the difficulty in analyzing sufficiently the various matings in which a weakened germ plasm becomes manifest. As far as practical consequences are concerned, the most important problem for us is how much of the causation of disease to attribute to an altered germ plasm and how much to environmental factors, and in particular what are the environmental factors which are responsible for the resulting inferiority. In this respect our knowledge also is as yet incomplete.

So far we have stated the principles which apply to the study of heredity in disease. We shall next review, very briefly, the part heredity plays in disease. A few diseases will be cited as examples of the different types of heredity in their relation to environment, in order to illustrate our preceding more general remarks. But before doing so, it might be well to state distinctly that not every case of transmission of disease from parent to child is of a hereditary character. If, for instance, the parents suffer from an infectious disease, like syphilis, and the child shows signs of syphilis at the time of birth, this merely means that the same microorganism which invaded the parent was transferred from the body of the parent to the body of the child, and thus the same disease from which the parent suffered was produced in the child. The disease in such a case is therefore not due to the transmission of a faulty germ plasm—and it is the latter condition alone which constitutes hereditary transmission—but it is due to an infection.

If we observe carefully a large number of individuals, we find that some of them admit of a classification into certain types according to their bodily and perhaps even their mental characteristics. These types represent what has been called the constitution of a person. Thus there has been distinguished an asthenic or weak type, a muscular or athletic type and a stout or pycnic type. Other types have also been observed. Now, some of these types lead to disadvantages in the process of living, but in particular it

has been noted that certain bodily structures or constitutions predispose of specific diseases. But what is of special interest is the observation that, in many cases at least, these constitutions are inherited and with them the tendency to certain diseases.

And not only this tendency is inherited, but it even seems that the duration of life itself depends upon a hereditary factor. Statistical studies in man indicate this conclusion, as well as experimental studies in certain insects. (Pearson, Pearl.) This, of course, does not mean that the duration of life is definitely predetermined in each individual; it merely means that among the various factors which do determine the length of life, heredity is one factor, for environmental conditions interact with heredity and largely influence the end result.

Now, if we pass over to the diseases proper in which heredity comes into play, we may mention in the first place certain malformations, due to so marked a faulty development of the embryo that visible abnormalities in bodily structure result. Supernumerary fingers and toes, hare-lip, cleft palate, pigmented moles and abnormal generative organs may be cited as examples. It is of interest that such rather crude malformations depend almost entirely upon hereditary factors. They are essentially due to the faulty reproduction of normal developmental processes, as those which normally lead, for instance, to the formation of fingers and toes in the young, and both the malformation and the development of the normal structure depend in the main on the character and the function of the germ plasm and are largely independent of variations which might occur in the environment. In certain cases, however, a malformation may be due to injuries received in the uterus, and in a few instances heredity determines only a part of the diseased condition, the full consequences of the change in the germ plasm becoming manifest only under the influence of external conditions acting in later life.

In a wider sense all hereditary disease or tendencies thereto are due to deviations in the structure or composition of the developing organism. In most cases these deviations are of a finer, more delicate character, not visible to the naked eye; but malformations in a strict sense represent, as stated above, rather crude, visible deviations from the normal.

One of the best studied classes from the viewpoint of heredity is diseases of the eye. Various errors of refraction, such as short and far sightedness and astigmatism, represent essentially hereditary alterations or malformations in the structure of the eyeball. Cataract is one of the common causes of blindness. It may appear in the young and then it is entirely due to heredity; or it may

appear in old people, and formerly it was thought that in the latter case cataract was due to environmental injuries, accumulating during many years of life; but it has recently been found that even in the typical cataract of old age, heredity plays an important part and that perhaps external injurious influences make the hereditary tendency merely manifest. We see here an example of apparently similar diseases being due to different causes and thus in reality representing different diseased conditions, and similar instances of this kind may be found in various other classes of diseases. Among other diseases of the eye due to heredity is night-blindness, and this condition has been traced in certain families from generation to generation for several centuries. Thus in some English families which suffer from this disease, all the cases can be traced back to a common ancestor in France, who himself suffered from night-blindness. A rather frequent disease of sight, in which the mode of hereditary transmission has been determined accurately, is the common kind of color-blindness. Here the hereditary character to which the disease is due is sex-linked and recessive. It is usually transmitted to the male offspring through the women, who themselves may be free from the disease. There are many other diseases of the eye, due to heredity, or in which at least heredity plays a part, but there are also other diseases of the eye which are due in the main to external factors, as, for instance, infections.

It will be interesting to contrast with malformations and diseases of the eye in which, at least in many cases, heredity plays the larger part, a class of diseases in which, on the contrary, the importance of environmental factors is quite evident. This is true of the infectious diseases, such as diphtheria, tetanus, smallpox, tuberculosis and many others. While undoubtedly external factors are dominant in these diseases, and no disease of this kind is possible without a preceding infection with the specific microorganism, yet even here inner hereditary factors play a certain part. Thus, it has been observed that certain acute infectious diseases may take a very much more severe course when they are first introduced among a new population hitherto not exposed to the disease. When the disease has once been established among a certain group of people, it seems to take a less virulent course and this probably indicates the influence of certain constitutional factors among that population, which possibly are of a hereditary character.

A good example of the action of hereditary factors in infectious diseases is found in tuberculosis. It has, for instance, been observed that this disease takes a somewhat different course in different families of guinea pigs and that this difference remains con-

stant in successive generations. In the human race the large majority of all children become infected with tuberculosis at some time in their life, but usually the disease takes a very light course. Upon this early infection the tuberculosis of adults may be superimposed. Now it has been found that constitutional factors of a hereditary character in a certain measure determine the disposition of an adult to fall prey to a tuberculous infection, and, moreover, hereditary conditions in association with variations in the mode of infection and in the virulence of the microorganisms largely determine the severity of the infection and the course the latter takes. In particular, individuals of an asthenic type, with a flat, narrow chest, are at a great disadvantage if tubercle bacilli gain an entrance in their body; yet not only hereditary factors, but also weakening environmental conditions may cause a predisposition to this disease.

A very well-investigated disease as far as the relative significance of environmental and hereditary factors is concerned, is found in tumors and in particular in cancer. If we briefly summarize our knowledge in this respect, we may state that some varieties of cancer are almost exclusively due to hereditary inner causes. In other kinds a combination of inner hereditary factors and of environmental stimulating factors is responsible for the disease; and still others are caused exclusively or almost exclusively by external conditions and here heredity plays apparently no or only a negligible rôle.

There are large classes of other diseases affecting our inner organs, as, for instance, the digestive system, heart, kidneys, thyroid gland, blood-forming organs and blood-vessels, and nervous system, in many of which heredity plays a more or less important part; but the significance of heredity varies greatly in different cases. Even in the same kind of disease a certain form may be mainly due to hereditary factors, while in another very similar form environmental injury is apparently of greater significance. Thus, in diabetes, as it is seen in young persons, a hereditary factor seems to be preponderating, while in the diabetes of older persons environmental factors play a much greater rôle than in younger persons. Certain kinds of goitre are mainly dependent upon the constitution of the germ plasm, while in other cases toxic substances or infections are responsible. In gout heredity plays a great part, and outer injurious conditions call forth the attack in predisposed persons. A very striking example of heredity is seen in hemophilia, the disease of bleeders. Small injuries, like cuts, may lead to long-continued bleeding, uncontrollable by ordinary means. This is an inherited disease; usually only men are

thus affected, but the disease is transmitted to the male offspring by the women. In this case we have therefore to deal with another example of sex-linked, recessive heredity. The disease can be followed through many successive generations, and it has been possible to trace families in this country to bleeder families in Europe.

From a social point of view perhaps the greatest importance attaches to the heredity of mental diseases. Mental abnormalities alter fundamentally the personality and social relations of the diseased person. A number of mental diseases are essentially due to environmental factors, as, for instance, progressive paresis, which is caused by the organism of syphilis, the spirochæte pallida. Syphilitic infection may in addition cause other mental disturbances, and the infection of the parents may be responsible for feeblemindedness in the offspring. Certain kinds of epilepsy likewise may be caused by environmental factors, such as injury. However, many kinds of mental deficiencies are to a great extent due to a hereditary abnormality of the germ plasm. Among these we might include certain varieties of feeblemindedness and idiocy. In a number of cases the history of families affected by such deficiencies has been traced back through successive generations, and there were found associated with feeblemindedness in various members of the family alcoholism and a tendency to criminality and to sexual excesses. While in such cases we have probably to deal with a combination of hereditarily transmitted tendencies and a very unfavorable mental environment, acting from early life on, yet the deficient constitution of the germ plasm is the predominating factor. Some of the most important mental diseases proper are largely due to hereditary changes in the germ plasm. This applies to the manic-depressive insanity in which melancholic and inhibited states or maniacal and elated states occur, or in which both of these alternate; it also applies to dementia præcox or schizophrenic insanity, which occurs mostly in younger persons and which shows very variable symptoms. In paranoia proper and in hysteria inherited tendencies likewise play a great part. Some of these inherited tendencies to mental diseases seem to be associated with definite bodily constitutions which are thus also inherited; and moreover certain mental patterns and temperaments which still fall within the range of the normal or are at the borderland between the normal and the diseased, and which are the equivalent of corresponding types of inherited mental disease, seem likewise in certain instances to be associated with these special bodily constitutions. We see in this case, as in others which we might have mentioned previously, a continuous transition be-

tween the inheritance of disease and of analogous normal characters, and both are due to the same underlying causes.

While thus in many cases of mental disease and deficiency there is no doubt as to the great significance of heredity, yet we must not therefore conclude that environmental factors, as, for instance, upsetting mental experiences, the effect of poisonous substances, play no part whatever in the origin of these inherited diseases. This latter possibility can not be disregarded at present, and it is impossible to foretell to what extent even hereditary diseases and deficiencies of the mind might not be prevented or mitigated, if we were able to provide a suitable mental environment, especially adapted to their needs, to predisposed persons from early years on.

The rapid survey of diseases in their relation to heredity, which we have now made, though it is of necessity very incomplete, suffices to indicate how important is the rôle of heredity in disease. The number of diseases in which heredity has been established as a cause is already to-day extremely great; yet we shall probably not be much in error if we foresee a still greater extension of their number as the chances for investigation become greater. We have also seen that there is, in very many instances, an interaction between heredity and environmental factors in the origin of disease. The relative importance of hereditary and environmental factors, in those diseases in which both act in association, differs greatly in different cases and it is not correct to speak in a general way of the significance of heredity or environment in inferiority and disease; each case must be analyzed separately to determine the part played by either of these two sets of factors.

Having now established the great importance of the hereditary constitution of the germ plasm in the causation of disease, we may inquire whether it is possible to make any statement as to the origin of a diseased germ plasm. At the present time we know positively of two conditions which may alter it in such a way that disease results in the organism, and in addition there is at least a possibility of a third condition: (1) The first well-established cause of a diseased germ plasm consists in the appearance of mutations, sudden changes in the composition of certain parts of the germ cells, in some cases at least due to a loss of a particle of the germ plasm. Such mutations, which are hereditary, are responsible not only for diseases, but also for other sudden changes in the constitution of an individual which still fall within the range of the normal. Mutations not only lay the foundations for a certain disease in the developing organism, but in some cases they cause the death of the fertilized egg before it has had a chance to develop fully. These latter mutations depend upon the introduc-

tion of so-called lethal factors. Mutations and in particular the appearance of lethal factors have been most thoroughly studied in the fruitfly, Drosophila, where the investigations of T. H. Morgan and his associates have led to a far-going analysis of the constitution of the germ plasm; yet the occurrence of such lethal factors is not restricted to Drosophila; they have been found also in higher animals. The causes for the appearance of mutations are not known at the present time. (2) The second class of causes underlying a diseased germ plasm is of an entirely different character. While in the case of mutations we are at the present time not aware of any influence due to external or environmental factors, the causes now under consideration consist entirely of injurious influences exerted by the outside world. Through the very extensive experiments of several investigators, among whom we may cite especially Stockard, it has been shown that if we expose animals, as, for instance, guinea pigs, for a long period of their life to a very pronounced action of alcohol, the offspring in successive generations will show definite inferiorities as to fertility and bodily vigor, although the members of these later generations have themselves not been exposed to the influence of alcohol. In some cases even malformations may appear in the offspring, especially malformations affecting the brain or the eye. These inferiorities may be transmitted by an alcoholized father as well as by an alcoholized mother; and not only the bodily characteristics are thus altered, but the mental capacity has been found to be diminished also, as in rats, the grandparents of which had been alcoholics. (MacDowell and Vicari.) However, it may be in certain instances that the action of alcohol, by weeding out the weakest germ cells, may actually lead to the survival of relatively strong individuals (Pearl). There is some ground for believing that other poisons, particularly lead, may act in a manner similar to alcohol. We may even consider the possibility that other unfavorable environmental factors, bodily or mental, may have a certain injurious effect on the germ plasm, provided they act through a very long period of time; yet, while we may consider such a possibility, we must be aware of the fact that an actual proof of such an effect has so far only been given in the case of certain poisons. (3) The third class of causes for the deterioration of the germ plasm is still under investigation at the present time. There is some indication that not only a general deterioration may be brought about through the action of toxic substances, but that, in addition, specific toxic substances or other specific interferences affecting a certain organ may cause such a change in the germ plasm that in the offspring similar defects in that particular organ,

and only in that organ, appear without interfering otherwise in the general condition of the individual which may remain normal. Such experiments have been made within recent years by M. F. Guyer, who produced experimentally defects in the eye of rabbits which were apparently transmitted from generation to generation. Of a similar character are possibly certain disturbances of equilibration in rats which have more recently been studied by Griffith and Detlefsen. If in these cases a hereditary transmission of specific somatic deficiencies should be definitely proven, the significance of these investigations would be very far-reaching, not only as far as the origin of disease is concerned, but also as a proof of the inheritance of acquired characters in general.

There is still another way by which a hereditary deterioration of the germ plasm and an increase in hereditary diseases may be brought about, namely, through continued inbreeding. Breeders of animals have for a long time past believed and they still are of the opinion that long-continued inbreeding produces unfavorable results, as far as the fertility and vigor of the offspring are concerned. The experiments of Shull and East in plants as well as the recent experiments of Sewall Wright in the Department of Agriculture, in Washington, have on the whole substantiated this view. Likewise in the case of man it has been observed that in communities where much inbreeding occurred, the results have on the whole not been favorable.

While thus some undesirable results follow inbreeding, inbreeding as such does apparently not produce a change in the constitution of the germ plasm in the sense in which mutations or the actions of certain poisons exert such an effect. Its influence depends in the main upon the joining together in the offspring of the same kind of deficiencies which in the parents had been dormant as recessive characters. It may be expected that, if relatives marry, they possess in a certain number of cases the same kind of latent weakness. Being present in double quantity in the offspring, this deficiency becomes in the latter potent and visible. It follows that if the germ plasm of both parents is perfect, close inbreeding would not only lead to a deterioration, but should even tend to preserve the good qualities of the ancestors.

It is thus possible under special conditions to continue close inbreeding over long periods of time and still to maintain vigor and fertility unimpaired. Thus in rats Miss H. D. King has shown that a deterioration as a result of inbreeding can be avoided by always mating together individuals especially selected for their vigor and fertility. Crossbreeding between different strains and races may have a beneficial effect, at least in the first generation

of the offspring, provided the distance between the two individuals is not so great that incompatibilities between the germ plasm arise.

We have seen that both hereditary conditions in the germ plasm, as well as injurious environmental factors, cause diseases and that in many cases both sets of factors interact and in a specific manner in particular diseases. We may foresee that in the future we shall discover additional hereditary factors, where we had previously only seen environmental injuries and, vice versa, we shall learn of associated environmental injuries, where in the past we had only known of fixed hereditary causes. At least this is what may be expected, if progress should continue to make the same course it has taken in the past, and if we consider that environmental factors are often hidden and become discernible only through careful experimental analysis. Moreover, we have learned that inner conditions as well as outer environmental factors may change the hereditary constitution of the germ plasm. So far, we can not yet be sure as to the permanency of the changes which have been induced in the germ plasm through the outside. It is not impossible that gradually a recovery may take place from the deficiencies thus produced, and possibly the future will teach us that the germ plasm may not only be influenced through injuries in an unfavorable direction, but also that on the contrary improvements may take place through favorable conditions, although at present we have not yet any information as to the existence of the latter kind of changes.

Is it possible to make use of the knowledge of heredity as a cause of disease, bodily and mental, in the conscious direction of human affairs, so that what is best and finest in human life is preserved and aided in its development? We might attempt to accomplish this by selection of those individuals which are endowed with the best germ plasm and by the weeding-out of what we consider the inferior germ plasm. Such a weeding-out process might be done consciously—and the Spartans attempted something of this kind many centuries ago—or it might be left to the ravages of nature, disease and poisons, or of a struggling human society through the means of various kinds of warfare. In cases in which individuals possess very pronounced deficiencies, especially of a mental kind, we are justified in discouraging the production of offspring in the interest of the individuals themselves thus affected, as well as of their potential offspring and human society in general.

But if we consider a further going use of this weeding-out process, there are some objections of the most serious nature to the application of such principles for social betterment. In the

first place each individual represents a great multitude of inherited tendencies, and there is some justification for the belief that in the large majority of all persons there are factors present which favor the development of one or the other disease and of certain bodily or mental inferiorities or undesirable peculiarities. And not only the kind of tendencies, but also the intensity with which these tendencies act, varies in different cases. Each individual represents a composite picture of the most intricate kind, and most parts of these pictures are entirely unknown to us, as far as the individuals are concerned, and individuals are the only real units in existence; neither do we exactly foresee at the present time, in many cases at least, the result which would follow from the combination of various factors, for instance of those which from a social point of view may apparently be indifferent, with other apparently equally indifferent factors. We would be prone at the present time, in very many cases, to select a few obvious characteristics, especially those making for bodily vigor, to the detriment of finer, less obvious characters. And there is, furthermore, some suspicion that each individual or social group would value most highly those characters with which they believe themselves endowed.

Moreover, our knowledge of the relative importance of environmental and hereditary factors is very incomplete as yet in the range of the normal as well as in the range of disease. Our everyday assumptions in this respect are often misleading and this applies to the conclusions of the laymen as well as to the views of the writers in this field, if their views are not based on very carefully analyzed evidence. In some cases we are prone to attribute to external factors what in reality is due to heredity, but in other cases we fall prey to the opposite tendency, to hold inner hereditary factors responsible for what is really the reaction of the organism to certain environmental conditions, physical or mental.

Furthermore, these methods would involve a weeding out which means some kind of destruction. There is danger that we thus would introduce or accentuate in our social and mental environment exactly those characteristics which are unfavorable to a finer and better life. We should therefore proceed with the utmost caution in recommending an improvement of human society by the process of selection and weeding out of germ plasms.

Excepting the conditions mentioned above, it seems at the present state of our knowledge preferable to attempt an improvement by spreading through education a knowledge of factors which are well established in the hereditary transmission of normal and

diseased conditions and to improve environmental conditions in such a way that the germ plasm is protected against the action of injurious influences, physical as well as mental, and perhaps even improved through the action of favorable conditions, if this should be possible. Furthermore, through our increasing knowledge of the injurious environmental factors without which certain inherited weaknesses or tendencies are not realized—and we may expect that the various institutions for the study of heredity in man, which have been founded more recently, as for instance, the Eugenics Laboratory at Cold Spring Harbor, will enlarge our information also in this respect—we may more and more obtain the ability to direct the environment in a manner most suitable for the production of healthy individuals; and this would apply to mental as well as bodily conditions.

Even if by these means individuals should be preserved, which in a ruthless struggle of life would be weeded out, we can not be sure that the qualities which are thus saved are not worth more than the bodily strength and the particular mental characteristics which were lacking in such individuals and which caused their inferiority in the struggle of life as it is constituted at present. But on the other hand, we can be sure that by applying these principles, we do not introduce into our life warfare and antagonisms and fears, which in the end would tend to vitiate the value of the price we seek, the development of human character and personality.

ORIGIN AND EVOLUTION OF THE INSECTS

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BEFORE attempting a discussion of the subject it may be well to obtain a somewhat clear idea of what is involved. There are something like 400,000 described species of insects, and the total number existing in the world has been variously estimated at from one to ten millions, the former being the minimum. These insects occur in all parts of the world and under very diverse conditions. They swarm in the tropics, and mosquitoes are so abundant in the Arctic regions as to make existence at certain seasons almost unbearable. Grasshoppers flourish in the open, grassy areas, while our extensive woodlands are the favored haunts of thousands. The waters have been invaded and we find peculiar forms in pools, lakes and rivers. A number prefer the brackish waters of the salt marshes, a few occur in the saline waters of the ocean, some delight in the super-saturated solution of Great Salt Lake in Utah and one species is found in petroleum pools. Great variations in size occur among insects. The Hercules beetle of Venezuela measures some six inches in length. A Venezuelan grasshopper has a somewhat greater length and a wing expanse of nearly ten inches, while one of the fossil dragon flies has a wing spread of more than two feet. These giants present a striking contrast to the more minute insects, some of which are only about one hundredth of an inch in length and find the requisite sustenance for a complete life-cycle within the speck-like egg of the codling moth.

Insects live upon our highest mountains as well as in areas below sea level and it is noteworthy that those occurring upon extremely high mountains are closely related or identical with Arctic species. We are concerned in the origin and evolution of this vast assemblage and in order to arrive at a correct solution it should be considered in its broader aspects.

If we compare insects with some of the related forms, such as the centipedes and the crayfish, it will be found that they are all bilaterally symmetrical and are composed of a linear series of rings or segments, bearing paired, jointed appendages and agree in having an external skeleton composed largely of chitin. Furthermore, the internal economy of these divergent forms is very

similar, the dorsal blood vessel or so-called heart occupying an upper median position, the digestive system a central position and the nervous system a ventral, median position, the last in the simpler forms at least with distinct swellings or nerve centers for the various segments. The general prevalence of this type through a considerable series of animals indicates a relationship and a common origin, in the judgment of many naturalists.

Turning to the insects once more, we may note first of all the prevalence throughout this immense group of one million or more forms with the general characters mentioned above and if we examined individuals more closely, it would be found that they may be divided by less general characters into immense series, such as the bees and related wasps, the beetles, the butterflies and moths, the true flies, the true bugs and a number of other less extensive divisions. If we refer to competent authorities in some of these groups, it will be found that even in America there are some 10,000 different species credited to the bee family, over 10,000 beetles, nearly 10,000 of the true flies, nearly 7,000 butterflies and moths and a very large number of species of true bugs. This means that there are immense series of very similar insects, some of which can be separated from close allies only with difficulty, and yet in most cases the differences are sufficiently marked so that there can be no real question as to the specific identity of this large number of forms. That is, each one of this enormous number of species breeds true and will continue to exist as a specific entity unless it succumbs to some combination of adverse conditions.

It is possible to go a little farther and find among insects relatively large groups of species belonging to individual genera or nearly related genera, the different species approaching each other closely in structure and general habit and yet presenting sufficient differences anatomically or biologically, usually both, so that no question exists as to the distinctness of these various forms. One of the most striking cases is found among the large series of cutworms belonging to the genus Agrotis, as originally defined, and now broken up into several closely related genera. There is a series of nearly three hundred of these species, the adults of which approach each other so closely that only very few specialists are able to distinguish between the different forms, and yet there are marked variations in the larvæ or cutworms, both as to coloration and habits. A very similar condition is found in the May or June beetles. Some appreciate their general resemblance to each other, and yet a recent list includes 97 species belonging to one genus and having for the most part very similar habits. The striking, active, vari-colored, yet very similar tiger beetles are

represented in this country by 75 species and what has been said of the June beetles is largely true of these latter. We may turn, if one prefers, to moths other than the cutworms mentioned above and find large series of very similar forms. In some cases, at least, these variations are evidently of advantage, since they distribute the chief feeding period of different species through the season and thus permit a given amount of vegetation to maintain without excessive injury a larger number of insects.

Somewhat the same condition, though on a less extensive scale, is found among mosquitoes, which up to within comparatively recent times were supposed to represent a nearly homogeneous group. Careful studies have shown, however, that this is far from the case. There are large series of mosquitoes presenting marked differences in structure and in habits, and in certain cases mosquitoes which are separable from each other with great difficulty in the adult condition are easily differentiated in the larval or wriggler stage by both structure and habits. A survey of an entire group, such as the mosquitoes mentioned above, the much larger and brilliantly colored flower flies or the very minute and almost unknown gall midges, show wonderful variations in structure and habits among insects possessing much in common and undoubtedly closely related to each other, and in certain instances at least these variations may reappear in a number of distinct lines within the same family. Take the gall midges, for example; there are variations in the number of antennal segments from six to forty-one, in the number of palpal segments from four to one, in the number of tarsal segments from five to two, and in the number of wing veins from six to none. It does not surprise one familiar with insect life that such variations should occur. There is food for thought, however, in the knowledge that these deviations from the more primitive or simple to the more specialized and complex should arise independently in a series of related groups easily separated from each other by general and relatively immutable characters. These modifications either have some relation to each other or have resulted from some other cause, possibly creative acts. Acceptance of the latter explanation viewed from the standpoint of the entomologist, conversant with the immense series of insects and their numerous variations in structure and habit from a comparatively few standard types, involves the acceptance as the true explanation of something like a million special creations for insects alone, or the development of many of the minor variations from a smaller number of special creations. A belief in the progressive change from the simpler to the complex, extending over millions of years and comprehending in its ultimate application the immense variety of

animal and plant life occurring upon the globe at the present day, is only the logical development of the former.

The precise formulation of our belief in regard to the origin and development of the animal and vegetable kingdoms is in one way a matter of minor importance, since no belief seriously affects present conditions, though it may modify our attitude toward life in general. It must be admitted that these conditions have significance and inquiry would show that most naturalists find a thoroughly logical explanation in an evolutionary theory which accounts for these multitudinous forms as deviations from common types, these variations being traceable in class, ordinal, family, generic and specific characters. Certain changes are going on at the present time, though at such a slow rate and by such imperceptible degrees as to be unrecordable, excepting in some of the plants and animals, the cultivated and domestic, which have responded to artificial environments to such an extent as to vary greatly from the original or wild type. Such variations can not be denied. It is well known that differences occur among wild species and in not a few instances it has been possible to recognize individuals in the same way as we distinguish between individuals of our own race.

Variations within specific lines occur among insects as well as in other forms of life. One of the most striking and well established is the well-known alternation of generations in gall wasps, a divergence so marked that alternate generations up to within a few years were recorded as belonging to different genera. Somewhat the same conditions are found among certain plant lice, except that it is more usually an alternation in series of generations rather than individual generations. Many species of plant lice have winged and wingless individuals, the difference apparently being due to environmental influences. The well-known chinch bug has a short-winged as well as a long-winged form, both being associated at times. Some butterflies present well-known seasonal variations, the colors of the two generations being markedly different. There are frequently well-marked variations between the sexes in insects, these sometimes being very pronounced, and in certain variable groups there are more or less incidental structural variations in the right and left antenna and possibly in other organs. These are brought to attention simply to emphasize the fact that variations do occur among insects belonging to the same species and occasionally at least in individuals. It is probable that no two insects are exactly alike in the same way as among the larger animals.

There is no denying the host of relationships and resemblances to be found in the present-day insect world. The naturalist has

long since learned to accept resemblances with a great deal of caution, because investigations have repeatedly shown that structures apparently identical and modified in a similar manner are in reality very different. Because of this the investigator approaches his problem from more than one aspect if possible and it is, therefore, suggested that with the above in mind we turn to the evidence presented in nature's records, the fossils of earlier ages. There has been found, for example, in the lower Silurian of Sweden a single wing doubtfully referred to the genus Protocimex, a possible prototype of Cimex, an insect which laymen mention with bated breath as the bedbug. Can it be that this insect was an associate of Pithecanthropus? Next comes a wing of Palæoblattina from the middle Silurian of France and a possible forerunner of the cockroaches of to-day. This latter suggests a further insect approach toward subhuman association.

If our geologists are right, these forms were found upon the face of the globe millions of years ago. There are some, however, who question their belonging to insects. If this be granted (it is really not necessary), there has been found in the slightly more recent Devonian strata the print of an ancient May fly wing and the remains of another insect suggestive of the cockroach, a nearer approach to subhuman association, so that the postponement of our acknowledging the presence of insect life upon the face of the earth is, relatively speaking, a matter of minor importance. Next comes the carboniferous or coal strata with its host of insect forms, some plainly closely related to our modern cockroaches. There is no denying the insect character of these carboniferous fossils. More recent strata show the continuance of these and related forms, and finally in the upper deposits there are undoubted representatives of our modern insects. The progression from the oldest insect-bearing strata to the most recent shows a gradual though not necessarily continuous development from what we regard as the simpler and more generalized to the more complicated and specialized insects of the present day. In other words, the history of insect life as traced in the rocks corroborates and strengthens the conclusions in regard to the development of the various forms gained by a study of the species living at the present time.

Turning once more to a consideration of insects and their allies, we would reiterate the fact that there is a very large group or class possessing a number of common characteristics, the Arthropoda, the forms with segmented legs and for that matter in large measure at least with segmented bodies. This is true of the crayfish, the spiders and their allies as well as the centipedes and millipedes, each representing an important and distinct group of approximately equal rank with the insects, though the last named is much

more numerous in species. A close survey of these groups of Arthropods would disclose species here and there presenting structures approximately intermediate between these large classes, indicating that during the progress of time—that is, the passing of geological ages running into millions of years—there has been a gradual splitting off or divergence of types from ancestral stocks and that by this process through almost endless ages there has developed the exceedingly abundant and variable group known as insects.

We have heard much of late about the teaching of evolution. Those who have accepted this explanation of the varied animal and plant life upon this globe find their justification in the life around them. The evolutionary theory is in large measure an attempt to explain the numerous variations, not only in insects but in all animal and plant life—variations that are meaningless if one fails to recognize a general plan of development or reaction to environment, if one prefers that term. It is to be expected that the geological evidence would be fragmentary if one makes allowance for the many agencies which would normally result in the destruction of every vestige of organic life and only occasionally present conditions favorable for its preservation in the everlasting rocks. The wonder, if any, is that the record is so nearly complete and that it harmonizes so closely with the evidence which has been secured from studies of animals and plants throughout the entire world, especially of those forms which evidently show relatively little change from an earlier primitive condition.

Development, evolution is freely admitted in the progress of civilization, the perfection of human relations and human devices and the better adaptation of animal and plant life to human needs. No one thinks of apologizing for the term "backward races." It is freely admitted that these have not developed or evolved to the same high standards as the more civilized peoples. The existence of "backward individuals" is also recognized, though not "socially." Many of the more progressive peoples accept the blessings of civilization and carefully avoid all reference to earlier and more primitive types of existence and some in continuance of this attitude display a consistent hesitancy to the recognition of evolutionary processes which may be seen in all branches of the organic kingdom, provided one has learned to decipher the records of nature. The revolution of the earth was denied, the circulation of the blood challenged, yet both continue in obedience to fundamental laws which can not be declared unconstitutional and in time all may accept the broader truths underlying the theory of evolution and that without contravening their allegiance to matters spiritual.

FISHERIES RESOURCES IN PERU

By ROBERT CUSHMAN MURPHY

THE AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK CITY

INTRODUCTION

THE Republic of Peru is entirely within the tropics, yet, owing to the effect of the cool Humboldt Current which flows northward in contact with its whole coastline, the littoral waters are of temperate rather than tropical character. This part of the eastern Pacific lies to the southward of the region of equatorial doldrums, and to the northward of the horse latitudes; it is marked, therefore, by equable, coastwise winds, and is without storms from one year's end to another. The continent is indented by a number of harbors suitable for the establishment of fishing bases, such as the bays, or protected roadsteads of Independencia, Chilca, Paracas, Callao, Ancon, Huarmey, Samanco, Ferrol and others. Finally, because of certain unusual hydrographic conditions, marine life is extraordinarily abundant. But in spite of all these favoring circumstances, there is not a single organized fishing industry along the twelve hundred miles of Peruvian shore line.

PRIMITIVE CONDITION OF THE FISHERIES

Few littoral waters of the globe teem with fish and with other edible products as do those of Peru, and yet in no other enlightened country are fisheries more restricted to methods which, with one illegal and disastrous exception (*i. e.*, dynamiting), are such as the Indians have followed from immemorial times. The modern Peruvians are highly appreciative of fish food, but, with the wealth of an exceptionally productive ocean at their door, they import their stockfish from countries within the northern hemisphere.[1] The waterfront fish-stalls of Callao are, indeed, well patronized, and a considerable quantity and variety of fresh fish are distributed through the great public markets of Lima, the capital; but the price of all but a few kinds is so high as to be prohibitive to the majority of the inhabitants. Two species, the bonito and the anchoveta, may be classed as staples; for the rest, the greater part

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CABALLITOS, OR REED BOATS
Stacked on the beach at Pacasmayo

of the aggregate catch in Peru is consumed in the communities of the Indian fishermen themselves, or in those of their more opulent near neighbors. In short, the coastal aborigines, continuing the customs of their ancestors, subsist upon a wide variety of sea products which comprise nearly all available kinds of fishes, as well as of molluscs and other invertebrates; the industrial landsmen of the seaboard towns utilize first the bonito and the anchoveta, and after these a limited number of dried or salted sea foods; while the well-to-do Peruvians confine their salt-water diet chiefly to a small selection of the most toothsome fishes, such as the flounders, corvinas and pejerreyes (silversides). The only shellfish which is commonly classed with such expensive delicacies is the scallop.

The present unsatisfactory condition of the Peruvian fishing industries, the fastidiousness of an important part of the population, the unequal utilization of sea food among the various classes of society, the relatively high cost of such food in the seaports and its extreme scarcity elsewhere, are all easily explained. They are due, in brief, to (1) certain underlying social and industrial causes connected with the former unstable economic condition of the Republic; (2) to the primitive methods employed and the lack of fish products plants of any description; (3) to the difficulties of transportation in a land of few railroads; (4) to the scarcity and high cost of manufactured ice; and (5) to the national, monopolistic control of the salt supply.

Native Equipment

The Peruvian fisheries as they exist to-day represent a some-

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Native Equipment

The Peruvian fisheries as they exist to-day represent a some-

what decadent native system slightly influenced by Mediterranean methods. The vast majority of the fishermen are pure-blooded Indians, whose equipment is doubtless not greatly different from that of the days before Pizarro. Such modifications as are found have been introduced mainly by maritime settlers of Italian stock, who now more or less predominate in the fisherman's vocation at the important centers of Ancon, Callao and Chorillos. The ordinary *chalupa* or fishing boat of central Peru is, of course, a Mediterranean type of craft—a double-ended, seaworthy boat, of broad beam, with no centerboard and a clumsy sailing gear. The centerboard, which would be a device of particular usefulness in this region of constant coastwise winds and currents, is unknown in Peru. The chalupas are used in all branches of the line and net fisheries, as well as for dredging, and, in spite of their intrinsic shortcomings, they are so well fitted out with the necessities of sea life that they serve as reasonably comfortable homes for the fishermen during voyages which sometimes take them for several days far from land.

Other more ancient types of craft used in the Peruvian fisheries are the *balsa*, the *canoa* and the *caballito*. The balsa is nothing more than a raft made of the extraordinarily buoyant Ecuadorian wood of the same name. Sometimes balsas are large enough to transport whole families, with their possessions, and are equipped with sails; but the fishing balsas which one sees on the beaches or carrying heaps of fish to the stewards of steamers in the northerly seaports of Peru are usually small and unrigged. They are propelled by means of one or two broad plank-oars, which the fishermen thrust straight down into the water at the stern and use as levers against the ends of the logs.

The *canoas*, made of Ecuadorian hard wood trees, of which one called the *guachapelí* is the favorite, are dugouts with planked-up gunwales. Sometimes they are forty feet or more in length. They are seaworthy when well manned, and, because of the density of the timber from which the best of them are constructed, it is said that they have a life of a hundred years or more.

The *caballito* or "pony," so-called because the fisherman sits astride it, is a very remarkable native boat made of bundles of reeds lashed together. It is a wonderful craft in heavy weather, riding breakers like a Hawaiian surfboard, and it is at the same time a thoroughly practical fishing boat when manned by an experienced native. A large caballito may have a length of fifteen feet, but it is so light, unless water-logged, that a man can easily carry it on his shoulders.

In the way of fishing tackle, many kinds of seines, drag-nets

A RIGGED BALSA OR FISHING RAFT
Talara, northern Peru. (Photograph by Harry Watkins; courtesy American Museum of Natural History.)

and casting nets, hand lines, trawls, dredges, and grains or spears, such as are common to most parts of the world, are used by the Peruvian fishermen. The seines are of various dimensions and meshes, each sort taking its vernacular name from the fish for which it is particularly designed: thus "pejerreyera," a net for pejerreyes or other small fish; "bonitera," of the right mesh for the bonito; "cazonera," a net for *cazones* or large sharks. The casting net or *atarraya* is employed chiefly in the surf of sandy beaches, and is identical with those which I have seen in use among West Indian and Brazilian fishermen.

Destructive Methods

The Peruvian fishermen, not content with the simple but effective equipment of their native fishery, have unfortunately acquired a new and fearfully destructive means of obtaining larger catches with less labor, namely, dynamite, the *chinchorro americano* or "American net," as it is called with grim humor. The illegal use of this explosive, which is widespread at least in central and southern Peru, bodes ill for the future of the Republic's marine resources, for the havoc that it wreaks among schools of fishes, and especially of young fry which are not worth picking up, can not fail eventually to cause a profound depletion of many species. Quantities of dynamite are naturally imported into Peru for use in the mines. By one means or another much of it comes into the hands of fishermen, who detonate it under water when they wish to obtain either food fish or bait. It is used with the latter object,

for instance, when anchovetas are destroyed as "chum" to attract corvinas or other large fishes to the surface, after which a second charge can be set off. In all phases of the dynamite fishing the destruction of life is generally greater than could be utilized even if a good proportion of the fish were not inevitably lost through their failure to rise or to remain afloat long enough to be scooped into a boat.

Popularity of Sea Food

As indicated above, the fisherfolk of Peru scorn few if any of the marine invertebrates which occur in profusion along parts of the coast. Not only are scallops, oysters, mussels, whelks, crabs and lobsters prized, but, moreover, squids and octupuses, holothurians, ascidians, sea-urchins, chitons and the "sand-bugs" or hippas of the sandy beaches are all utilized in one form or another. The molluscs of Peru apparently furnished a considerable part of the food supply of the ancient Indians, as they do of their successors, for in graves among old burial grounds at Chorillos and Paracas Bay I found the shells of many species which are still sold in the fish markets of Callao.

Some of the molluscs which are valued for food are taken on the rocks, in the sand of the beaches, or on mud flats exposed by the falling tide, but scallops, oysters and *caracoles* (snails) are often obtained by dredging in relatively deep water. One mollusc which formerly promised to support a valuable fishery in northern Peru, and which may once again assume importance, is the pearl oyster (*Pteria peruviana* Reeve), the same species which is the basis of a pearl fishery in the Gulf of California.

Opportunity for Fish Product Plants

Upon visiting so rich a seacoast, any one with a knowledge of fisheries can not fail to be impressed by the unrealized opportunities for the development of desiccating, canning and packing plants in Peru. Aside from many available fish, and such species of molluscs as the giant mussel, which might be preserved for distribution in the same manner that clams are canned on the west coast of Florida, the bays of Peru abound in an unusual variety of large edible crabs, some of which are similar to the crustaceans upon which the Japanese have based their extensive export trade in crab-meat. Lobsters (*Palinurus*), related to those which the Chileans pack in tins at Juan Fernandez, are likewise common in parts of the coast. So far as I have learned, no sea food of any kind is canned in Peru, the only familiar native marine products being dried or salted fish of many sorts, pickled anchovies and preserved fish eggs and sea weed.

A DREDGING CHALUPA
Laden with scallops, Callao.

A CANOA, OR DUGOUT, AT CHUCUITO
The fishermen's beach of Callao.

Variety of Fish Life

Although the entire Peruvian coast lies well within the tropics, its shore fish fauna is in general of subtropical or temperate rather than equatorial character. The reason is, of course, to be sought in the conditions of oceanic circulation produced by the Humboldt Current. Peruvian fishes are, in a zoogeographic sense, comparable with Mediterranean fishes rather than with those of the Atlantic coast of America. In both Peru and the Mediterranean region we find an admixture of tropical species with others which are distinctly temperate or even northern, such as the *jurel* or scad (*Trachurus*). The closest faunal affinities of the Peruvian fishes are with those of the Californian littoral, which lies just outside the tropics in the northern hemisphere. Many species are common to both of these widely separated areas.

If we group the Peruvian fishes according to their environmental affinities, rather than their zoological relationships, we find aggregations of species adapted to all types of habitat that exist along the coast. Thus there are (1) many kinds of rockpool fishes; (2) numerous species specialized for life on rocky bottoms of greater depth, and (3) others, like the flounders and some of the rays, which are particularly characteristic of sandy bottoms and shallow water; (4) schooling, plankton-feeding forms, like the herrings and anchovetas, are impressively abundant, while these are pursued by a great variety of (5) larger predacious fishes, among which are the mackerels, barracudas and the free-swimming types of sharks. Only anadromous fishes, like the alewives and

salmon of North America, are unrepresented in the Peruvian assemblage.

Important Fishes of the Coast

A brief consideration of a few of the more important Peruvian marine fishes, group by group, may prove of interest.

1. ***Sharklike Fishes.*** These include a score of species of dogfish, sharks, angel-fish, skates, rays and chimeras or ratfish. Certain representatives of these families are common in all parts of the coast, but it is in the north, near the point at which the Humboldt Current mingles with warmer equatorial waters, that the sharks, guitarras and rays are found in greatest numbers. At Lobos de Tierra and Lobos de Afuera Islands an important fishery is carried on by the northern maritime Indians, both the rays and the sharks, including hammerheads and other species up to seven or eight feet in length, being prepared as dried or salted products. So far as I learned, the valuable liver oil yielded by many of these fishes is seldom utilized. Neither are the hides saved, although, as has been recently demonstrated in the United States, they can be converted into superior leather.

2. ***Herrings.*** Of the three Peruvian species of herrings, the best known are the *sardina* (*Sardinella sagax*) and the *machete* (*Potamalosa notacanthoides*). Both of these migrate in enormous schools which sometimes fill the bays, supplying sustenance to larger fishes of more value to man, as well as to certain sea birds, and to the sea lions. On the calm morning of November 14, 1919, I crossed Pisco Bay when the shining surface, ruffled only by an occasional puff of wind, enabled me to obtain a clear view of such multitudes of herrings as I had never previously beheld. At one time I counted thirty distinct schools of *sardinas* within a quarter of a mile of my launch.

It seems probable that a Peruvian *sardina* fishery, conducted in the manner of the menhaden fishery, would prove profitable. The relative oil yield of the *sardinas*, as compared with menhaden, has not been determined, but it is altogether likely that several marketable products, including "kippered herring," oil, "fish guano," and an ingredient of cattle and poultry food could be derived from them. For the use last suggested, the dried fish-scrap might be combined with cotton-seed waste, of which there is always an unutilized surplus in the country.

3. ***Anchovies.*** This family is dominated by the anchoveta (*Engraulis ringens*), a fish not exceeding six inches in length, the most abundant and important fish of the entire Peruvian littoral, the mainstay of the bird guano industry, and a food fish of high rank. Like the sardina, the anchoveta subsists upon minute forms

ROCK FISH FROM THE BALLESTAS ISLANDS

Left to right: 1, "mulata" (*Pimelometopon darwinii*); 2, "babunco" (*Doydixodon laevifrons*); 3 and 4, "cabrilla" (*Paralabrax humeralis*); 5, "ojo de uva" (*Hemilutjanus macrophthalmos*); 6, "burro" (*Sciaena fasciata*); 7, "chavelita" (*Chromis crusma*); 8, "chita" (*Anisotromus scapularis*).

of plant life, such as diatoms and other algæ, and possibly upon small pelagic crustaceans. The fishes travel in schools of incredible size, the immature examples being sometimes visible as red dots among the massed adults. They are followed incessantly by larger fishes, sea lions and birds of very many species. Myriad numbers of the anchovetas, at least when conditions in the Humboldt Current are favorable, are likely to be found at any point along the entire Peruvian coast-line.

During the afternoon of February 2, 1920, while on board a steamer off Huarmey, I estimated that a hundred schools of anchovetas were within sight. At times, when the bonitos attacked them from beneath, large areas of the surface would be so broken by the leaping of the little fishes that the ocean hissed as though a deluge of rain were descending upon it. The most remarkable sight of all was the manner in which whole herds of sea-lions were lolling and frolicking among the anchovetas, gorging themselves to the limit of their capacity.

On other occasions I have had the good fortune to run directly over schools of anchovetas in a launch of shallow draft. Their appearance from above is amazing, for the quivering, silvery creatures seem to be packed together like sardines in a tin, except that their heads point all in one direction as their legion, which somehow seems more like an individual organism than a conglomeration of millions, streams through the gauntlet of its diverse and ubiquitous enemies.

The abundance of the anchovetas is indicated also in other ways, for it has been conservatively estimated that *thousands of tons of*

CHORILLOS, SUBURB OF LIMA
With fishing boats at their moorings.

these fishes per day are devoured by sea birds which breed in colonies of hundreds of thousands, and even of millions, on some of the Peruvian islands.[2]

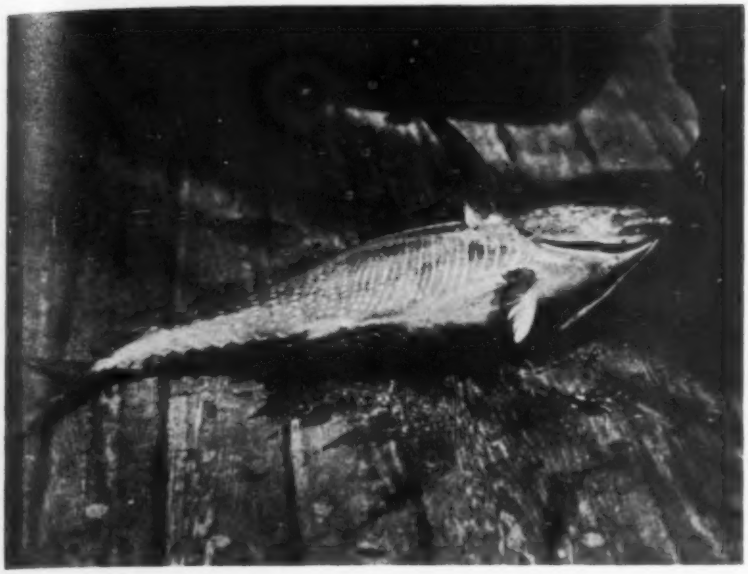
The anchovetas have from early times been crudely preserved in Peru by mixing them with salt earth. Sacks of this dried product find their way far into the interior. The anchoveta would make a tinned product of excellent quality, but since the species is the principal food of the valuable guano birds, the question of granting a concession for an organized fishery would need thorough and unprejudiced investigation. It is probable, however, that the anchoveta occurs in great excess of the needs of the birds, across the entire width of the Humboldt Current; in any case, an almost unlimited modern purse-net fishery would be less disastrous for the species than the present practice of dynamiting.

4. *Flying Fishes.* These fishes, which are characteristic of warmer pelagic waters, well off shore, come into the Humboldt Current along with dolphins and other tropical species during the southern spring and summer (November to February).

The flying fish are not in themselves important food fishes in Peru, but their egg-masses are dried to form a product known as *cau-cau.*

5. *Silversides* (Atherinidæ). Of this widely distributed family, the small marine pejerrey (*Basilichthys affinis*), which, like the

2 See R. C. Murphy: "The Guano Industry of Modern Peru," *Brooklyn Museum Quarterly*, Vol. 7, p. 259, 1920.



A LARGE TUNNY (*Germo Argentivittatus*)
Of a species sometimes common in the northern waters of the Humboldt Current.

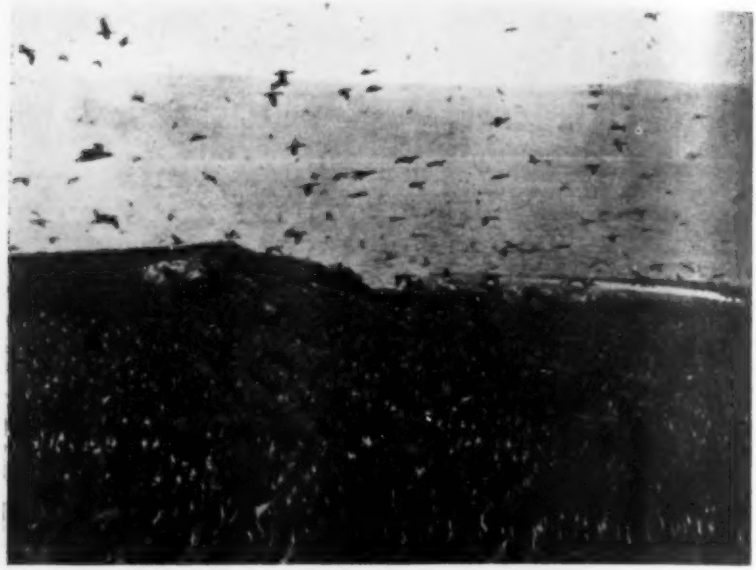
anchoveta, occurs in great schools, is probably the most delicious eating of all Peruvian fishes.

6. *Mullets.* The *lisa* (*Mugil cephalus*) is a prized and abundant fish. Mullets of this and related species are often stranded in great numbers upon the mud flats of such inlets as Independencia and Paracas Bays.

7. *Mackerels.* The representatives of this family include two very important fishes, the *caballa* or common mackerel of the country (*Scomber japonicus*), and the bonito (*Sarda chilensis*). The latter, because of its abundance and cheapness, constitutes the foremost item of marine food among the poorer people of the whole coastal region. The *caballa* also supports a considerable fishery, being taken chiefly on hand lines. Quantities are salted at the Lobos Islands and elsewhere. The *caballa* is a fish of fine flavor, and its relatively low repute in Peru is doubtless due to the fact that broiling is an almost unknown or unpracticed method of cooking fish. Prepared in any other way, the flesh of the *caballa* is too oily to vie with that of species more favored by Peruvians.

A local fishery for the *peje-espada*, or swordfish, which is a relative of the mackerels, is conducted from the port of Mollendo.

8. *Carangids.* A well represented family of which the *cojinova* (*Neptomenus crassus*), the *jurel* or scad (*Trachurus*), and the far-



FISH-EATING BIRDS ON SANTA ROSA ISLAND

These cormorants live chiefly upon anchovies, and the astounding abundance of the birds is an index of the remarkable fisheries resources of the Humboldt Current.

famed pámpano (*Trachinotus paloma*) are the most important Peruvian members.

9. *Sea Basses.* A family of many species, of which a number, such as the *cherlo* (*Acanthistius*), the *ojo de uva* (*Hemilutjanus*), the *cabrilla* (*Paralabrax*), and the several species of fishes known as *cabinsas* are familiar even though not highly regarded food fishes.

10. *Croakers and Drums.* Another well-represented group, with two or more species related to our North American squeteague or weakfish, together with two of the finest fishes of Peru, the *corvina* (*Sciæna gilberti*) and the robalo (*Sciæna starksi*). Both of the latter attain large size, sometimes weighing forty pounds, and both fetch a high price in the markets. These fishes always congregate at the outlets of the Peruvian rivers in times of flood, for the purpose of feeding upon small crustaceans which find their way from the fresh water into the sea.

11. *Flounders.* Flounders and their relatives are common and of good quality.

12. *Blennies.* The several kinds are plentiful, occurring everywhere about the islands and along rocky shores. Perhaps because of their abundance and grotesque appearance, and the fact that they are often a nuisance to fishermen, the blennies figure more or

A SCALLOP-DREDGING CHALUPA
With modified lug-rig. Callao: Fronton Island in the background.

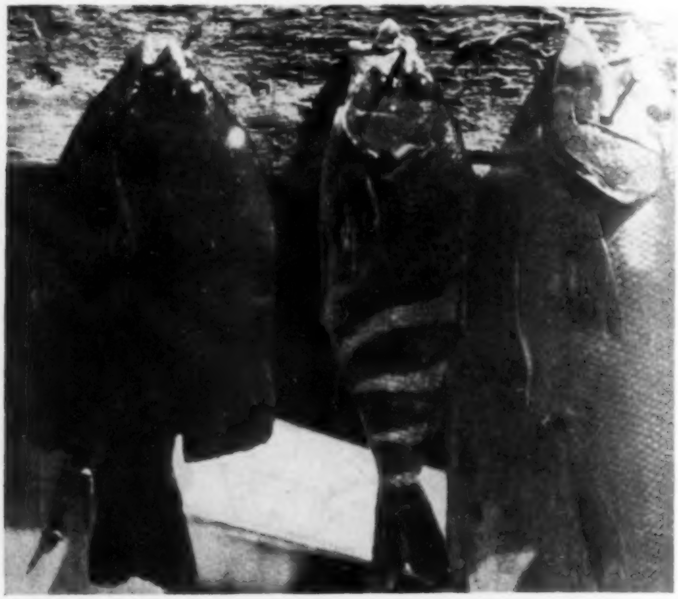
less in folk-lore of the Peruvian coast. Thus two or three species are known as *borracho,* which means drunk. Fishermen at several places told me that eating the *borrachos* would produce intoxication or stupefaction. At the Chincha Islands I heard one species of *borracho* called also *sueño* (dream), the implication of which is no doubt similar.

13. *Cusk Eels.* The family of the *congrio* (*Genypterus*), an abundant and highly prized food fish, especially in the southerly parts of the coast. The *congrio* is sometimes known as the *bacalao del país*, or "native cod," for it furnishes a desiccated food of first rank. The principal *congrio* fishery is in the vicinity of Mollendo, where the fishes are taken on trawl lines. Their reputation, however, extends to all parts of Peru.

At North Chincha Island I saw many *congrios* caught. The lines were set on dark nights, the legend that these fish would not take hooks in the moonlight evidently being fully credited. Excellent catches were made and I was able to observe the native method of preparing the famous *charqui* or *charquecito.* The fresh fish were split down the back, and, after cleaning, were soaked in the cool sea water for twenty-four hours or longer, until the blood had diffused out. Finally they were hung in the air, without salting, until the white flesh had thoroughly dried.

EARLIER ATTEMPTS TO INTRODUCE IMPROVED METHODS

The opportunity for initiating more efficient and extensive



CHARACTERISTIC ROCK FISH FROM THE BALLESTAS ISLANDS
Left to right: 1, "mero" (*Oplegnathus insignis*); 2, "pintadilla" (*Chilodactylus variegatus*); 3, "mulata" (*Pimelometopon darwinii*).

fisheries operations in Peru has occurred to many persons and has, indeed, been tried, although thus far without success. More than a century ago Joseph Skinner wrote:

"The fishery is a branch of industry exclusively belonging to the Indians situated on the coast; but they are destitute of skill, and, being at the same time unprovided with proper boats and fit instruments, keep constantly within sight of the coast, venturing but a very small distance to sea. Hence arise the scarcity and dearness of fish, so often experienced at Lima, and in all the places along the coast. A few years ago several boats of a particular construction were built for the purpose of fishing throughout the whole extent of these seas; but this scheme was shortly afterwards abandoned.[3]"

Not many years ago, a trawling venture was undertaken, the Scotch steamer "Alcatraz," which subsequently passed into the hands of the National Guano Administration, being employed with modern equipment for some months. The bottom proved rocky in most places, and hence not satisfactory for this type of fishing, but fish were, nevertheless, taken in abundance. The problem of a sufficient market, however, ultimately led to failure, for, when the sea-

[3] "The Present State of Peru," London, 1805, p. 8.

ports had been glutted with fish, means were lacking for transporting the catch to centers where it would have been in demand.

Conclusion

Beyond doubt organized fishing in Peru will eventually be conducted with success. The resources are great and varied; the bays offer inviting sites for stations; native fuel oil is obtainable in quantity; adaptable labor is already on the ground; the climatic conditions of the coastal ocean are almost without parallel; the government is eager to see the country's natural resources developed. A rich potential market exists along both coasts of South America and in the interior, besides which it is likely that many prepared products might profitably be exported to the Orient and even to the northern hemisphere.

INVERTEBRATE ANIMALS AND CIVILIZATION

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IT is probable that man had his origin in a single locality and from there migrated to different regions of the earth, moving about "like the other migrating faunas, unconsciously, everywhere following the line of least resistance, advancing or receding, and acting generally on blind impulse rather than of any set purpose. . . . and further that these migrations took place prior to the development of all cultural appliances beyond the ability to wield a broken branch or a sapling, or else chip or flake primitive stone implements."[1] Thus man assumed his present erect posture and certain structural features long before he developed those religious, moral and intellectual faculties which we call human characters. Probably he was more or less social from the beginning.

From the common center of origin early man migrated to all parts of the earth's surface, and has given rise to the various races and tribes we now know, as well as to others which have become extinct. The facts also seem to force the conclusion that out of the original brute-like and instinctive life and activities have developed the variety of customs, activities and cultures found to-day in different races, including our complexly organized industrial life and the highly developed intellectual society of modern times. The migrations and the changes in habits as well have been influenced by or conditioned upon the many physical factors of the environment, such as climate, geographical location, geological and physiographic conditions. Likewise, the biological factors of the environment have influenced or determined the rate and kind of progress; the importance of plants and of the higher animals, especially mammals, for food, clothing and shelter are well known.

The lower animals have also contributed to the advancement and civilization of man, and to a much greater degree than most of us suppose. At the present time the chief competitors of man are the insects, and we must wage war with vigorous and unceasing

[1] Keane, A. H.: "Man Past and Present," Cambridge Univ. Press, 1900, p. 8.

activity to grow our food, protect our forests, our animals and ourselves from their attacks.

The following account will outline some of the relations of the invertebrate animals to man and the ways in which they may have assisted in the progress of his civilization. No attempt will be made to secure an exhaustive discussion, but only to suggest in a general way some of the many relations which might be considered.

Land Masses

The land areas of the earth's surface are due mainly to geological activities, the formation of beds of sedimentary rocks and their elevation above the water level. But considerable areas are due, directly or indirectly, to the lower animals. Of these animals the corals are the best known, and the great number of coral islands scattered through the Pacific Ocean have furnished places of habitation for many peoples. These tiny animals, living in great colonies and building great masses of lime as their skeleton, can not grow above water, but the fragments are broken loose, fill in the spaces between the branching corals, and other fragments are ground into sand which the waves pile above the water level. Later this sand may be consolidated into rock. In this way the Bermuda and Bahama Islands have been formed. The southern one hundred miles, or more, of Florida is built of limestone formed chiefly from coral sand and Yucatan and many islands of the West Indies are partly formed in the same way. Growing with the corals are great numbers of crustacea, clams and snails, starfish and sea-urchins and tube-forming worms; the calcareous shells of all these are ground up and help to form the sand which is consolidated into limestone.

Clams and snails have lived in great abundance, as they are now living, and in past ages have left masses of shells in enormous beds. These have been fragmented, sometimes ground into sand, and later consolidated into such rocks as the shell limestone or coquina of St. Augustine, Florida. In all parts of the world similar shell limestone is present, often in great abundance.

The lowest of the animals, the Protozoa whose microscopic body is composed of a single cell, contribute their remains to the formation of new deposits. Some of the Protozoa are encased in shells of lime for protection, and at death these shells drop to the ocean floor and form thick masses of soft ooze. Investigators of the sea floor have found all over the world masses of ooze which are composed almost entirely of these shells. This foraminiferan ooze is the most widespread of modern calcareous formations, over fifty millions of square miles of sea bottom being covered mainly by

the shells of foraminiferan Protozoa. When consolidated the accumulations form chalk. Beds of chalk extend from Ireland across Europe to the Caucasus Mountains, and from Sweden to France, the beds being a thousand feet thick in places. Such chalk beds were formed from foraminiferan ooze in past ages.

The lower animals have therefore contributed effectively and considerably to the formation of the land upon which man could live.

Soil

Soil is composed of disintegrated rock with organic substances intermingled. Invertebrate animals have contributed to the formation of the soil to the same extent that they aided in the production of the rock. However, it is in the preparation of the soil for plant growth that the invertebrates play a very large part.

In his book upon "Vegetable Mould and Earthworms" Charles Darwin gives a detailed account of the action of worms upon the soil. The earthworms pass earth through their bodies, grinding it in the gizzard into very fine particles and digesting out some of the organic matter which may be present. The earth itself passes out of the body again and is deposited at the surface of the burrows as castings. In this way deep-lying soil is brought to the surface, the earth is reduced to a very fine condition and mixed with organic matter. The burrows of the worms permit aeration of the soil, allow drainage and make pathways for the growth of roots. In many parts of England Darwin estimated that ten tons of earth for each acre of land is passed through the bodies of earthworms and brought to the surface each year. If this finely divided soil were spread out in a uniform layer over the land it would amount to a thickness, in some cases, of an inch to an inch and a half in ten years.

Darwin sums up the results of his observations and experiments as follows: "Worms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds. They periodically expose the mould to the air and sift it so that no stones larger than the particles which they can swallow are left in it. They mingle the whole intimately together, like a gardener who prepares fine soil for his choicest plants. In this state it is well fitted to retain moisture and to absorb all soluble substances, as well as for the process of nitrification. The bones of dead animals, the harder parts of insects, the shells of land molluscs, leaves, twigs, etc., are before long all buried beneath the accumulated castings of worms, and are thus brought in a more or less decayed state within reach of the roots of plants. Worms likewise drag an infinite number of dead leaves and other parts of

plants into their burrows, partly for the sake of plugging them up and partly as food.

"It may be doubted whether there are many other animals which have played so important a part in the history of the world as have these lowly organized creatures."[2]

Others have stated that the work of the earthworms is of greater significance and of more importance to man than perhaps all of the geological and physiographic factors combined.

Food

Primitive man was a plant-eater, subsisting upon roots, tubers and especially upon fruits. This has been determined from the character of the teeth in the jaws of primitive man. Gregory shows that man has passed through three stages in regard to character of teeth and food habits: (1) a chiefly frugivorous stage, (2) a predatory and omnivorous stage, (3) a stage in which food was softened by cooking. He outlines a possible explanation for the change from vegetable to animal food as follows: "At a time when tough-rined tubers and fruits were still the main element of the diet the nascent Hominidæ may have sought out the lairs and nesting places of many animals for the purpose of stealing the young and thus they may have learned to fight with and kill the enraged parents. They had also learned to fight in protecting their own nesting places and young."[3] To account further for the assumption of the predatory habit Gregory suggests that primitive man may have learned to use a stone to mash tough plants or to break bones; later he learned to throw stones, to use sharp stones as knives, to swing a piece of wood and so gradually came to the use of weapons and implements. After he learned to use weapons he became primarily a hunter and ceased to depend chiefly upon vegetable food.

These suggestions imply that man secured his animal food by hunting the larger forms, especially birds and mammals, and no doubt these were the chief dependence when they could be obtained. But we have evidence that great use was made of invertebrate animals as well. This may have been only at certain seasons or by certain tribes, but it was a widespread habit as is shown by the great refuse heaps of shells (kitchen-middens) found all over the world, in North and South America, Europe, Australia, New Zealand, Japan and other regions. In places such refuse heaps are fifty to seventy feet wide, twenty feet thick, and extend

[2] Darwin, Charles: "Vegetable Mould and Earthworms," D. Appleton & Co., 1900, pp. 312, 316.

[3] Gregory, Wm. K.: "Studies on the Evolution of the Primates," *Bull. Amer. Museum Nat. Hist.*, Vol. 35, p. 342.

for a thousand feet or more; they must have taken centuries to form. Lord Avebury[4] states that such shell heaps mean that communities of men lived there subsisting on molluscs and depositing the refuse shells in a heap. The evidence shows that these dwellers were permanent settlers and not merely summer visitors. In describing such kitchen-middens in Denmark Avebury mentions the chief mollusc shells as the oyster (*Ostrea edulis*), mussel (*Mytilus edulis*), cockle (*Cardium edule*) and periwinkle (*Littorina littorea*); but whelks (*Nassa* and *Buccinum*), clams (*Venus*), land snails (*Helix*) and other shells were present with a few remains of crabs and bones of fish, ducks, deer and wild boar. In every part of the world, along the seacoast, man lived almost entirely upon molluscs; the remains of other animals are so few as to show they were occasional and not staple articles of diet.

The dependence upon shell-fish for food and the formation of kitchen-middens is not limited to prehistoric man. Darwin[5] found that the inhabitants of Tierra del Fuego lived almost solely on shell-fish, varying this diet only with a few berries and fungi, an occasional putrid carcass of a whale or seal which drifted ashore, and a few fish captured on lines without hooks. These people constantly changed their place of residence but returned again and again to the same localities and kept adding to the shell heaps. When storms prevented the gathering of shell-fish the people went hungry, and they often suffered severely from famine. Darwin also found that on Chiloe and other islands of southern South America the Indians lived chiefly upon shell-fish and potatoes, though fish were sometimes caught, and rarely they kept a few pigs, sheep and fowls.

Subsistence wholly on shell-fish is no longer common, but the use of molluscs as a part of the diet is almost universal. Highly civilized races, and savage tribes as well, include a greater or less number of such forms in their food. In this country probably fewer kinds of molluscs are eaten than in any other civilized country, only the oyster and some of the clams suiting our tastes. May it not be possible that the experimentation of primitive man in the use of various shell-fish in different parts of the world accounts in part for the different tastes of living man?

The following molluscs are used as food to-day in various parts of the world: Bivalves—mussel (*Mytilus*), oyster (*Ostrea*), scallop (*Pecten*), fresh water clams (*Anodonta, Aetheria*), *Cardita*,

[4] Lord Avebury: "Origin of Civilization and the Primitive Condition of Man," Longmans, 6 ed., 1900.

[5] Darwin, Charles: "Journal of the Voyage of the Beagle," Appleton, 1905.

Pompano (*Donax*), surf or hen clam (*Mactra, Tresus, Lutraria*), quahog (*Venus*), great blue clam (*Schizothærus*), blunt nose clam (*Macoma*), *Tivela, Tapes*, cockle (*Cardium*), giant clam (*Tridacna*), bear's paw (*Hippopus*), *Panopæa*, soft clam (*Mya*), razor clam (*Solen, Siliqua*), rock-boring clams (*Lithodomus, Saxidomus, Pholas, Pholadidea*); Univalves or snails—limpet (*Patella*), Abalone or ear shell (*Haliotis*), shield shell (*Scutus*), top shell (*Trochus*), turban (*Turbo*), sea snails, bleeding tooth (*Nerita, Neritina, Navicella*), *Murex, Purpura*, hare's ear (*Concholepas*), whelks (*Buccinum, Eburna, Neptunea, Nassa*), *Voluta*, auger shell (*Tenebra*), moon shell (*Natica*), periwinkle (*Littorina*), pond snail (*Paludina*), apple snail (*Ampullaria*), conch (*Strombus*), pelican's foot (*Aporrhaïs*), *Triton*, sea hare (*Aplysia*), roman snail (*Helix*) and chitons; among the cephalopods, the devil fish (*Octopus*), squid (*Loligo*) and cuttle fish (*Sepia*).

No other group of invertebrates has formed so staple an article of diet from the earliest times as have the molluscs. Primitive man did make some use of crustacea, since the skeletons of crabs have been found in kitchen-middens, but these were clearly not much sought for, possibly because of greater difficulty in capture. In modern times many crustacea appear on our bill of fare: lobsters (*Homarus, Palinurus, Scyllarus*), shrimps and prawns (*Crangon, Palæmon, Peneus, Pandalus*), crayfish (*Astacus, Cambarus, Panulirus, Iasus*), crabs (*Cancer, Callinectes, Ovalipes, Carcinus, Birgus*), mantis shrimp (*Squilla*) and others.

Insects are used as food mostly by savage tribes, though Arabs and Syrians gather locusts, pull off the wings and legs and eat the roasted bodies, or they dry the locusts in the sun and preserve them for future consumption. The American Indian gathered the nymphs of the 17-year cicada as they emerged from the ground, roasted them in a hot oven, or pounded them to make a sort of batter which was cooked and eaten; the same practice is followed by Indian tribes in central New York to-day. The Australian natives are recorded as eating ants, caterpillars, moths, beetles and grubs of all kinds either raw or cooked, and night-flying moths are pounded into a paste and cooked. African natives use the large fleshy grubs like those of our May beetles, and also other insects, pounding the bodies of May flies into paste. Hans Coudenhove[6] has described the food habits of living African natives as follows: "The natives catch the winged termites or white ants. devour them alive, devour them dead, raw or fried or roasted, or dried in the sun, or pounded to a paste. They pack them in bags like beans, alive or dead, and sell them on the market." "Several kinds of

[6] Coudenhove, Hans: *Atlantic Monthly*, October, 1921; March, 1922.

caterpillars, both smooth and hairy, are collected in baskets and eaten as a relish; locusts and white ants replace in the native cuisine our oysters and turtles; and some people are particularly fond of a large, strong-smelling tree-bug." "Up to fifteen years ago in the so-called Kaffir eating houses on the Rand, native mining boys used to buy, by preference, meat full of grubs. They said it was richer."

The segmented or annelid worms are not commonly used as food by man, but some of the nereids are eagerly sought for by natives of Tonga, Samoa and the Fiji Islands. At the breeding season these worms swarm to the surface of the sea in countless numbers to spawn. The Palolo worm (*Palolo viridis*) appears on two days in October and on two in November of each year at certain phases of the moon. Saville-Kent[7] states that the natives assemble the night before the appearance of the worm, which by them "is regarded as one of the daintiest luxuries their territories produce." When the swarming begins, about dawn, the worms are scooped into canoes with hands, nets and other receptacles. In the feast which follows the worms are eaten raw or wrapped in plantain leaves and baked. Quantities are sent inland to other tribes. A similar worm with similar habits is eaten by the natives of the New Hebrides.

Echinoderms, though apparently without attraction to most people, are eaten by some. In France and Italy large numbers of the common sea-urchins are used as food, and the natives of the West Indies eat the large urchin *Tripneustes*. The trepang or Bêche-de-mer of the Chinese is made from the dried bodies of the sea-cucumbers, *Stichopus* and *Holothuria*. These are gathered in Australia and elsewhere from the coral reefs, boiled in water, the body cut open and eviscerated and dried in the sun; they may also be smoked after drying. When thoroughly dry they are packed and shipped. Saville-Kent records several hundred tons of dried trepang as shipped from Queensland, Australia, in a single year.

Ornamentation

That some sense of beauty is inherent in man is indicated by the care and ornamentation he gives to his person and his effects. Such a sense seems to have been present from the beginning. The expression of this sense in primitive man and in living savages seems very strange and perverted to civilized people. But from the savage viewpoint our own sense of beauty is just as strange and unaccountable.

Probably in primitive man, and certainly in savages, orna-

[7] Saville-Kent, W.: "The Great Barrier Reef of Australia," London, 1893.

mentation commonly takes the direction of smearing or painting the body with colored earth or pigments, and tattooing or mutilating the body. But in addition all sorts of objects are used for adornment in the form of necklaces and the like. The shells of molluscs are perhaps among the oldest and most common objects used for ornamentation. Either in the natural state, or modified by grinding into beads and fragments, shells were constructed into necklaces, armlets, bracelets, anklets, nose, ear and lip ornaments. Shields, war and hunting implements, drums, canoes and other appliances were decorated with shells. Large and uncommon or striking shells were used as symbols of rank and influence in the tribe. No doubt almost all of the common shells have been used in this way, especially if they were attractive in form or color.

With the progress of civilization comparatively little change has occurred in the matter of adornment. We still use necklaces, bracelets, ear and finger rings. Instead of lip and nose ornaments and tattooing, we ornament our clothing, and civilized people still powder and paint the exposed portions of their bodies. Among the invertebrates used by living civilized people the molluscs furnish the greatest variety. Articles of jewelry, brooches, rings, studs and buttons are made from *Haliotis, Turbinella, Cypræa, Turbo, Trochus, Meleagrina*. Mother-of-pearl is obtained from *Haliotis, Meleagrina* and others. Pearls are obtained from a variety of molluscs, chiefly from the pearl oyster (*Meleagrina margaritifera*), but also from fresh water clams of the family *Unionidæ*, and from marine clams, as *Ostrea, Venus* and *Tridacna*. Occasionally green pearls are found in *Haliotis*, pink pearls in *Strombus*, black pearls in *Pinna*. Cameos are cut from several of the marine snails as the queen conch (*Strombus gigas*), bull's mouth helmet (*Cassis rufa*), black helmet (*Cassis cameo*), and the orange helmet (*Cassis cornuta*). The pearl buttons we use come mostly from the shells of fresh water clams of the Mississippi valley, some forty-one species being of commercial value.

Aside from the molluscs only the precious red coral (*Corallium rubrum*) among the invertebrates furnishes us with material for jewelry.

Ornamentation is accomplished by clothing, aside from the adornments added, and other invertebrates have been of service in furnishing dyes to man. One of the most famous of the dyes was the Tyrian or "Phoenecian purple" of Mediterranean peoples. This was obtained from marine snails of different sorts, chiefly *Murex* and *Purpura*. Heaps of shells of *Murex trunculus* are still found along the Tyrian coast and *Murex brandaris* on the Greek and Italian shores; along with these are different species of

Purpura. The molluscs were pounded in hollow rocks, the fluid so obtained separated by squeezing, water and soda added and the liquor boiled. Wool dyed with this is stated to have been worth $200 a pound, and only royalty could afford its use.

The cochineal insect (*Coccus cacti*) lives upon cactus plants of the prickly pear group in Mexico, but has been introduced and cultivated in South America, Spain and Algiers. The bodies of the insect were brushed into bags and killed by immersion in hot water or by exposure to steam or sun. From these dried bodies the red dye carmine was obtained, which was especially valuable for staining wool a brilliant red. A similar red dye obtained from the lac insect has for centuries been used in India. Dyes obtained from the cochineal and lac insects have been almost replaced by the synthetic chemical dyes.

Money

While the method of barter was the first means of acquiring materials or appliances, it is certain that a definite medium of exchange was devised very early in the progress of civilization. Shells were used as money by ancient man, and even to-day some savage tribes pay their taxes and acquire merchandise and property with shell money. The eastern American Indians obtained their wampum by making beads from the shells of marine molluscs. White beads were made from the whelks (*Busycon carica*, *B. canaliculatum*, *Baccinum undatum*) or quahog (*Venus mercenaria*). The more valuable purple beads came from the purple portions of the shell of the quahog. In California and on the west coast the Indians strung the shells of the elephant's tooth shell (*Dentalium*) and used these strings as money. A string of twenty-five shells might be worth a canoe or a comely woman. It is said that in the early days this money was so abundant that "every Indian possessed an average of at least $100 worth of shell money. This would represent the value of about two women, or two grizzly bear skins, or twenty-five cinnamon bear skins, or about three average ponies."[8] In addition to the use of Dentalium Stearns[9] states that the west coast Indians also made beads or disks from *Olivella*, *Haliotis*, *Fissurella*, *Saxidomus* and *Pachydesma*.

In the Pacific islands, India and Africa the money cowry (*Cypræa moneta*) was the principal shell used as money, though *Cypræa annulus*, *Littorina*, *Nerita* and *Ovula* shells were also used. The cowry is probably still used in parts of Africa to a limited extent, where formerly it was the sole medium of exchange and

[8] Rogers, Julia E.: "The Shell Book," Doubleday, Page & Co., 1908, p. 300.

[9] Stearns, R. E. C.: "Aboriginal Shell Money," *Amer. Nat.*, 1877, Vol. 11.

used in the paying of taxes, the purchase of wives (which might cost from 25,000 to 100,000 cowries, depending upon age, beauty and the like) and all other purposes which money would serve. An old story, attributed to Reeve, is that of a house built in India and paid for entirely in cowries, sixteen million being required.

Industries

Mention has already been made of the formation of limestones from the remains of invertebrate animals. There are many limestones which have an organic origin, such as the shells of foraminifers, fragments of coral, of crinoids, of mollusc shells of various sorts. Most of these are valuable for building stones. The nummulitic limestones which were largely used in the building of the pyramids of Egypt are consolidated foraminiferan shells. In Bermuda and elsewhere the coral limestones furnish most of the stones for building. Thomson[10] refers to the excellence of this coral limestone in Bermuda. "The stone is cut out of the quarry in rectangular blocks by means of a peculiarly constructed saw, and the blocks, at first soft, harden rapidly, like some of the white limestones of the Paris basin, on being exposed to the air." Coquina limestone, composed of cemented fragments of mollusc shells, has also been used for building purposes in Florida.

The only road metal available in certain regions of the world consists of the shells of recent molluscs. These are often found in enormous beds and are either broken up and applied to the road or used as obtained and ground up by the traffic. Without such material to draw from it would be impossible in certain parts of Florida, for example, to construct hard roads without great expense from imported material. In other places the shell and coral limestone is crushed for the building of roads.

Chalk is too soft and friable to furnish building stones, but it serves a no less valuable purpose as an ingredient of paints, cements and putty. Lime may be obtained from chalk and also from shells and shell limestone.

The lac insect (*Coccus lacca*), which is allied to the cochineal and other scale insects, furnishes us with our only source of shellac. These insects, which pierce the bark of twigs to secure the sap as food, secrete a resinous substance over the entire body as a protection. This hardens into scale like plates, and since the insects are usually present in great numbers, the twigs and branches of the shrubs may be entirely enclosed within this resinous substance. The twigs covered with the encrusted insects are gathered and

[10] Thomson, C. Wyville: "The Atlantic" (Narrative of the *Challenger* Expedition), Harpers, 1878.

this furnishes the "stick lac" of commerce; if the resin is crushed into fragments and washed in hot water we have "seed lac," while the "shell-lac" is obtained by melting the resin, straining it through canvas and drying in thin layers. We are entirely dependent upon this insect for our shellac, which is the principal ingredient in sealing wax and other cements; its chief use, however, is in the making of fine varnishes and lacquers.

Dynamite, so necessary in construction work, is composed of nitroglycerin mixed with an inert absorbent material. One of the most satisfactory absorbents for this purpose is infusorial or diatomaceous earth. The former consists of the silicious shells of unicellular animals, while the shells present in diatomaceous earth are those of unicellular plants. Other materials besides this infusorial earth may be used as absorbents of the nitroglycerin, but this seems to be one of the most satisfactory.

Arts and Sciences

Just as the invertebrates have contributed to various industries, they have in some measure aided the arts and sciences. The ink used by man to express his thoughts was formerly obtained chiefly from gall nuts, those from oak trees being more abundant, though such galls occur on many plants. The galls were powdered and the extract leached out and mixed with an iron salt. Such ink became blacker after writing, due to oxidation, and thus made a valuable ink since it entered the fibers of the paper and was difficult to remove or erase. The galls are plant growths, but such growth is stimulated by small insects, usually gall wasps. The insects lay their eggs in the leaves or stems of the plants, and the hatching and growth of the larva stimulates the plant to the growth of this gall, which serves as a sort of nursery for the developing animal. Gall nuts formed the basis for the tattooing colors of some savages.

The sepia pigment and the india ink of artists was at one time obtained only from cephalopod molluscs, such as the cuttlefish, octopus and others. The scientific name of the cuttlefish is *Sepia*. These molluscs contain an ink gland which secretes a fluid used for protection by the animals. In China the animals were thrown into vats and the ink collected as it exuded from the dead bodies. In Mediterranean countries the ink sac was removed, carefully dried and powdered, the powder dissolved in caustic alkali and then precipitated with acid. After washing in water and drying, the powdered sepia was ready to be made up in any form required.

If one were to suggest that our knowledge of the heavenly bodies and progress in astronomy or that careful surveys and measurements of terrestrial distances were dependent upon the lower animals, he might be considered as not quite normal. Care-

ful and accurate measurements are essential in such work, and these demand micrometers of various sorts. The cross hairs in micrometers for telescopes, microscopes, theodolites and other similar instruments are often composed of strands of spider web, which, because more delicate, may serve better than metal wires.

Hence, in a measure the advance of these sciences may be dependent upon the spider.

Medicine

Records are wanting as to what, if any, use the invertebrates were to primitive man in medicine. But civilized races in different parts of the world have had weird ideas as to the effectiveness of invertebrates in a great variety of human ills. Many of these practices are doubtless still in use by ignorant people as home remedies, but only a few centuries ago they were the standard and approved methods of the leading medical men.

Snails, especially the garden slugs, seem to have been favorites for all kinds of treatment, as we may judge from the many records of their use. For headache a plaster was made from the bodies of these slimy animals; for tuberculosis they were boiled in milk and the mixture drunk, or small living slugs without any previous treatment were placed on the tongue and swallowed without crushing. Pliny suggests eating an uneven number of them to cure cough and stomach ache. One of the royal physicians of England, as reported by Hulme,[11] recommends for deafness: "Take a gray snail, prick him, and put ye water which comes from him into ye ear and stop it with black wool, and it will cure." Slugs have been used for corns, pleurisy, malaria, burns, asthma and skin diseases.

Until about fifty years ago the leech was much esteemed as a sovereign remedy for everything; it was equally effective for apoplexy and for fainting, for fever and for chills; the first thing the physician did was to clap leeches on the patient and thus bleed him. Records show that seven million leeches were used in London hospitals in 1863 and more millions were used in other cities and countries. Leech farms were conducted for the purpose of raising leeches to supply this need, and drug stores kept a constant supply on hand. In older days leeches had other values and Pliny gives a recipe for a hair dye obtained from them: "Leeches left to putrefy for forty days in red wine stain the hair black. Others, again, recommend one sextarius of leeches to be left to putrefy the same number of days in a leaden vessel, with two sextarii of vinegar, the hair to be well rubbed with the mix-

[11] Hulme, F. E., "Natural History Lore and Legend," London, 1895.

ture in the sun. According to Sornatius this preparation is, naturally, so penetrating that if females, when they apply it, do not take the precaution of keeping some oil in the mouth, the teeth, even, will be become blackened thereby."[12]

Ashton records the ancient use of river crabs as remedies for poisoning. These are used fresh, beaten up and drunk in water, or they are burned and the ashes mixed with asses' milk as an antidote for scorpion poisoning. The ashes in red wine is good for rabies.

Insects had their place in ancient pharmacopeias, and Williams[13] quotes an old Egyptian formula: "Against all kinds of witchcraft a great scarabæus beetle; cut off his head and wings; boil him; put him in oil and lay him out; then cook his head and wings, put them in snake fat, boil and let the patient drink the mixture." Dental pains were cured by placing a small caterpillar in the cavity of the tooth and closing it up with wax. The use of cantharidin continues to the present day as a blistering agent, and this is obtained from the dried bodies of certain beetles called blister beetles.

The spider was chiefly useful for chills and contagion. Hulme[14] records the use of a living spider shut up in a box and carried around to draw from the air the contagion which would otherwise infect the person. From a diary of 1651 this entry is quoted: "I took early in the morning a good dose of elixir, and hung three spiders about my neck, ague away, Deo gratias." In southern England the spider was a favorite remedy for jaundice. Pills were made from spider web, or a living spider was rolled in butter to make a pill, which was taken.

Such records show that the invertebrates were believed to have great merit as remedies for certain diseases and ailments. In our modern pharmacopeia we have discarded all such, and most other of ancient animal drugs, but we have retained many of the plants used by the ancients.

Religion

The invertebrate animals have not had the same appeal to man for religious rites as have the vertebrate animals and inanimate objects. But there are a number of these lower animals which have been considered sacred. To the Hindus the chank shell (*Turbinella pyrum*) is a very sacred object, and images of the god Vishnu carry this shell in one hand. The shell is an object of veneration to the people, who address their petitions to it at the

[12] Ashton, John: "Curious Creatures in Zoology."

[13] Williams, H. S.: "History of Science," Vol. 1, p. 48.

beginning of each prayer. Priests make sacred vessels of the shell, which may be carved and ornamented for this purpose.

The scarab beetle (*Scarabæus sacer*) was one of the many animals sacred to the Egyptians, and symbolized to them the sun and the earth. Avebury[4] refers to one of the beliefs of the Pacific islanders as follows: "The Bishop of Wellington informs us that spiders were special objects of reverence to Maoris; and, as the priests further told them that the souls of the faithful went to heaven in gossamer threads, they were very careful not to break any spider's web."

Modern Civilization and Insects

We suffer enormous money losses each year in this country from the attacks of insects upon our food and other crops, upon live stock, forests and in other ways. In other places one may find the statistics dealing with these great losses which exceed two billions each year. Apart from this actual damage insects may influence or actually condition certain of our activities. The spread of the cotton-boll-worm through the southern states seems destined to change entirely the agricultural policy and practice of these regions. The growing of cotton as the principal crop is being replaced by a diversity and rotation of other crops, with cotton only one of the products. In other words since we can not overcome nor successfully meet the attacks of this insect we must change our habits.

Perhaps the most striking examples of the influence of insects on modern civilization relate to the insects as carriers of disease. Celli in his book on malaria states that the greater activity and industry found in northern Italy, as compared with southern Italy, is due to the prevalence of malaria in the latter region. And he further suggests that the growth of cities and development of agriculture in parts of Italy has been determined by the prevalence of malaria. This determination is therefore due to the presence of the mosquito, for the malaria is spread only by this insect.

It was the mosquito which prevented the French from cutting a canal at Panama, and it was only when our own sanitarians conquered the mosquito that we were able to complete the work. In all tropical and sub-tropical climates the handicap which the white man has had to endure, and the reason for the lack of colonization, and therefore for the spread of his civilization to these regions, is the prevalence of fevers. And this involves the presence of mosquitoes and biting flies, for in all probability all the tropical fevers are spread by insects. Man can live in the tropics safely and healthfully if he can subdue the insects which carry disease; the evidence of this is clear and positive from the record of the United States in Cuba, Panama and the Philippines.

There is no group of animals, vertebrate or invertebrate, which has so much significance to man as the group of insects. They touch almost every activity and interest of civilized life. They attack our growing food, our stored food, our orchards and forests, our clothing and our dwellings. Our bodies and those of our domestic animals are annoyed or infected with disease germs through the activities of insects. They are our chief competitors in the struggle for existence, and our fight against them is getting more severe and costly every year. Howard[14] has stated it as a matter of doubt whether in the next few centuries man will be able to maintain himself against this group, or whether he will succumb and leave the earth to the insects as the dominant type of animal.

When we consider such a possible outlook we have a striking, not to say startling, impression of the relationships of man and the lower animals.

[14] Howard, L. O.: "The Contribution of Zoology to Human Welfare," *Science*, 1918, Vol. 47, p. 352.

FOOD CONTROL DURING FORTY-SIX CENTURIES[1]

By MARY G. LACY

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THE man, or class of men, who controls the supply of essential foods is in possession of the supreme power. The safeguarding of the food supply has therefore been the concern of governments since they have been in existence. They had to exercise this control in order to hold the supreme power, because all the people need food, and it is the only commodity of which this is true.

In connection with this control it would seem that every possible expedient and experiment had been tried. One of the most frequent methods of control used has been the limitation of prices by legal enactment. The results have been astonishingly uniform considering the variety of conditions and circumstances under which the experiments have taken place. They make an interesting record and one which contains food for thought, for the problem of the people's welfare has been much the same in all ages and it is not yet solved.

EGYPT: 2830 B. C.

As far back as the fifth dynasty in Egypt, which historians place at 2830 B. C. at the latest, there was inscribed on the tomb of the nomarch Henku: "I was lord and overseer of southern grain in this nome."

In the Book of Genesis[2] there are various references to the fact that Egypt was a granary where all the people were sure of finding a plenteous store of corn.

[1] No attempt has been made in this paper to cover the history of price-fixing since 1800. Government monopolies, such as the Brazilian valorization of coffee, the tobacco monopoly in France and that of sugar in Germany, as well as others which might be mentioned, have been fully reported by others. The history of price-fixing in the United States during the war of 1914-18 has also been written in the bulletins of the War Industries Board on the history of prices during the war. Litman gives a good account of Great Britain and the United States in his "Prices and Price Control in Great Britain and the United States during the War."

[2] Genesis xii: 1-10; xli: 54; xlii: 2.

The well-known story of Joseph shows how the control of the food supply by the government reduced a people to slavery. Joseph gathered and stored for Pharaoh in years of abundance one fifth of all the harvests. The improvident Egyptians lived well and laid by no stores. When famine came they and the people in the nearby countries went to Joseph and bought food from him until all their money was gone; then they gave him their cattle for food; after they had bartered away all their cattle they offered their land and themselves in exchange for subsistence. Having thus reduced them to slavery as the price of life, Joseph about 1700[3] B. C. gave them seed and put them on the land again. Flavius Josephus[4] tells the story as follows:

When famine came, the multitude, sorely oppressed, repaired in crowds to the stores and magazines of the king. The situation of the poorer and common sort was piteous beyond description; for having laid in but a very scanty store, and not being able to obtain a supply without ready money, when that was exhausted, they were reduced to the necessity of exchanging their cattle, slaves, lands, nay, their last little all, to procure grain from the king's granaries to protract a needy miserable life. When, by these means, they became totally destitute, they were abandoned to a desolate world, that the king might secure their bartered possessions. . . . But when at length the river overflowed, watered the earth, revived drooping nature, and produced a fertile aspect, Joseph made the tour of the kingdom, and summoning the respective landholders, restored to them such parts as they had sold to the king, on condition of their paying a fifth, as tribute to him by virtue of his prerogative and then enjoined them to the same diligence in their improvements, as if they were to derive the emoluments resulting from the whole. Transported at the returning prospect of plenty, and the restitution of their landed property, the people applied themselves to agriculture with unremitting assiduity; so that by this well-timed act of policy, Joseph established his own authority in Egypt, and increased the standing revenue of all its succeeding monarchs.

The great Egyptologist, Erman,[5] corroborates the testimony of Josephus by giving an account of the government control over grain and descriptions of the granaries which were surprisingly like our elevators—the grain being poured in at the top and taken out at the bottom by means of a sliding door. The outstanding

[3] Some scholars place the date at 2082 B.C. and still others at 1500 B.C. It was probably in the reign of Aphobis, at the end of the seventeenth dynasty, according to Dr. Henry Brugsch, in his history of Egypt under the pharaohs. Trans. by Philip Smith (London: John Murray, v. 1, pp. 300-306).

[4] Josephus, Flavius: "History of the Antiquities of the Jews." Ed. by George Henry Mayard. London: C. Cooke, 1789. Bk. 11, Chap. VI and VIII.

[5] Erman, Adolf: "Life in Ancient Egypt." Tr. by H. M. Tirard. London and N. Y.: Macmillan & Co., 1894. Pp. 107-108, 433-434.

Original sources: Lepsius, Richard, "Denkmäler aus Aegypten und Aethiopen," Berlin: 1849-59. Vol. 3, pp. 76, 77. Papyrus Abbott, published in the "Select Papyri in the Hieratic Character from the Collections of the British Museum." London: 1844-60.

result of the Egyptian control of the grain crop was a system of land tenure by which the land became the property of the monarch, and was rented from him by the agricultural class.

CHINA: 424-387 B. C.

In his study entitled "The Economic Principles of Confucius and His School," Dr. Chen[6] tells us that in China it was recognized from early times that

> . . . there are two sets of interests, those of producers and those of consumers. But nothing more markedly affects the interests of both sides at once than prices. Therefore, price is the great problem for society as a whole. According to the Confucian theory, the government should level prices by the adjustment of demand and supply, in order to guarantee the cost of the producer and satisfy the wants of the consumer.
>
> Its chief aim is to destroy all monopoly so that the independent or small producer can be protected on the one side, and the consumer on the other. It prevents the middle-man from making large profits, and gives the seller and buyer full gain. It is the task of the superior man to adjust demand and supply so as to keep prices on a level.

The means used by the Chinese government to this end are of the greatest interest, because of the economic principles involved and also because of their antiquity.

We are told that, "according to the official system of Chou (about 1122 B. C.) the superintendent of grain looked around the fields and determined the amount of grain to be collected or issued, in accordance with the condition of the crop; fulfilling the deficit of their demand and adjusting their supply."

> When Li K'o became the minister of Wei he said that if the price of grain were too high, it would hurt the consumers, and that if it were too low, it would hurt the farmers. If the consumers were hurt the people would emigrate, and if the farmers were hurt, the state would be poor. The bad results of a high price and a low price are the same. Therefore, a good statesman would keep the people from injury and give more encouragement to the farmers.

After describing the bad condition of the farmers he gives the following law for equalizing the price of grain:

> Those who want to equalize the price of grain must be careful to look at the crop. There are three grades of good crops: The first, the second and the lowest. In an ordinary year one hundred acres of land yield one hundred fifty bushels of grain.[7] In the first grade of good crop the amount is fourfold—that is, one hundred acres yield six hundred bushels. Throughout one year, a family of five persons needs two hundred bushels for their living, so

[6] Chen, Huan-Chang: "The Economic Principles of Confucius and His School." N. Y.: Longmans, Green and Co., 1911. (In Columbia Univ. Studies in History, Economics and Public Law, v. 44 and 45.)

[7] It is evident from the context that "grain" as used in these translations means *rice*.

that they have a surplus of four hundred bushels. The government should buy three hundred bushels from them, leaving them a surplus of one hundred bushels. In the second grade of good crop, the amount of grain is threefold—that is, one hundred acres yield four hundred fifty bushels. The family would then have a surplus of three hundred bushels. The government should buy two hundred bushels, leaving them one hundred bushels. In the lowest grade of good crop, the amount is twofold—that is, three hundred bushels. The family would then have a surplus of one hundred bushels. The government should buy fifty bushels and leave them the other half. The purchase of the government is for the purpose of limiting the supply according to the amount demanded by the people, and it should be stopped when the price is normal. This policy will prevent the price of grain from falling below the normal and keep the farmers from injury.

There are also three grades of famine: the great famine, the middle famine and the small famine. During the small famine one hundred acres yield two thirds as much grain as in the ordinary year—that is, one hundred bushels. The government should then sell at the normal price what it has bought in the lowest grade of good crop. During the middle famine, the hundred acres yield one half as much grain as in an ordinary year, that is, seventy bushels. The government should now sell what it has bought in the second grade of good crop. During the great famine the amount of grain is only one fifth of what it is in an ordinary year—that is, thirty bushels. The government should sell what it has bought in the first grade of good crop. Therefore, even if famine, flood and drought should occur, the price of grain would not be high, and the people would not be obliged to emigrate. This would come about because the government takes the surplus of good crops to fill the insufficiency of bad years. In other words, the government controls the excess of supply in a good year in order to meet the demand in a bad year.

The policy of Li K'o is for the benefit of both society as a whole and the agricultural class . . . when his scheme was carried out in Wei, he not only made the people rich, but also made the state strong.

The principle of adjusting the supply and demand of grain is found also in the writing of Mencius, who lived 372-289 B. C. Dr. Chen quotes him as saying to King Hui of Laing:

When the grain is so abundant that the dogs and swine eat the food of man, you do not make any collection for storage. When there are people dying from famine on the roads, you do not issue the stores of your granaries for them. When people thus die, and you say, "It is not owing to me; it is owing to the year," in what does this differ from stabbing a man and killing him, and then saying, "It was not I; it was the weapon"?

The starving millions of China during 1921 might well have wished for so statesmanlike an advocate in the councils of their government as this fearless economist three hundred years before the Christian era. Dr. Chen proceeds to say:

The principle of equalizing the price of grain advocated by Li K'o and Mencius was adopted into the system of "constantly normal granary." During the reign of Han Hsuan Ti, when there were good crops for many years, the price of one bushel of grain was as low as five pennies. Then the farmers suffered greatly. In 498 (54 B.C.) Keng Shou-ch'ang proposed that the government should buy grain from places near the capital instead of

transporting it from the eastern provinces. According to the old custom of the Han dynasty, the government transported annually from the eastern provinces four million bushels of grain to supply the capital, which was in the province of Shensi in northwestern China. As this transportation was by means of the waterway, the number of laborers amounted to sixty thousand. By the plan of Ken Shou-ch'ang, which was approved and carried out by the emperor, the government saved more than half the expense of transportation, and the farmers got more profit. Then Ken Shou-ch'ang proposed that all the provinces along the boundary of the empire should establish granaries. When the price of grain was low, they should buy it at the normal price, higher than the market price, in order to profit the farmers.

Dr. Chen points out that the equalization of the price of grain is a very beneficial and practical scheme. It benefits the people without cost to the state. When the price is too low, though the government buys the grain at a price higher than the market rate, this does not mean a waste to the government. When the price is too high, though the government sells the grain at a price lower than the market rate, it does not mean a loss to the government. Even if it should be an expense to the government the social benefit is much greater than the public expense. On the contrary, as a matter of fact, the system has been more than once administered so as to make money for the government.

The few criticisms which have been made of it are shown by Dr. Chen ". . . to be the results not of the original law itself, but of the administration of man. The chief difficulty in administering it is that it is not easy for officials to undertake commercial functions along with political duties."

ATHENS: 404-337 B. C.

Xenophon tells us that in Athens a knowledge of the grain business was considered one of the qualities of a statesman. This was probably because Attica needed a considerable importation of grain, as the country did not produce a sufficient amount for its needs. It was brought to market in the Piræus from all quarters, from Pontus, Thrace, Syria, Egypt, Lybia and Sicily. A great quantity was imported, but not all for domestic use—some of it was to be sold in the Piræus to foreigners. It has been estimated by Boeckh that Attica needed annually 3,400,000 medimni[8] of grain, about half of which it could produce in a good season. This left, as the lowest of needed importations, 1,700,000 medimni or 1,133,-333 1/3 bushels. In an unpropitious season, when the domestic crop was scanty, this amount of importation was far from sufficient, so that one of the first objects of an Athenian statesman was to provide for an adequate supply of imported grain, and the

[8] A medimnus was equal to two thirds of a bushel or eight gallons.

regulations in regard to the grain trade were very important. Boeckh,[9] in his "Public economy of the Athenians," says:

> The exportation of grain was absolutely prohibited. It was required by law that two thirds of the grain which came from a foreign country to the Attic emporium should be brought into the city: that is, only a third of the grain brought into the emporium in the Piræus could be exported from it to other lands. The execution of this law was committed to the overseers of the emporium.
>
> In order to prevent as much as possible the accumulation of grain and the withholding it from sale, forestalling it was confined within very narrow bounds. It was not allowed to buy at one time more than fifty backloads (about 75 bushels). The transgression of this law was punished with death. The grain dealers were also not permitted to sell the medimnus of grain at a higher price than one obulus (three cents) more than they had paid for it. These dealers, who were commonly aliens under the protection of the state, enhanced the price, notwithstanding, by overbidding others in the purchase of grain in time of scarcity, and they often sold it the same day on which they purchased it at an advance of a drachma (17.1 cents) on the medimnus. Lysias can not relate particulars enough respecting the profligacy of these extortioners. They were hated full as much as the same class in modern times. . . "Were they not menaced with the punishment of death," said he, "they would hardly be endurable." While the agoranomi (market masters) had the superintendence of the sale of all other commodities, the state, in order to prevent the extortion of the grain dealers, appointed a particular body of officers called the sitophylaces (grain inspectors) to have the oversight of this single business. . . . They kept accounts of the grain imported, and besides the oversight of grain, they had also the inspection of meal and bread, that they might be sold according to legal weight and price.

The oration against the grain dealers delivered by Lysias[10] about 387 B. C. is of the greatest interest because of the light it throws on the speculative practices of the grain dealers in Athens, the great wheat market of the eastern Mediterranean and the attempts of a harassed government to control them. From it we glean that, in spite of the rigorous laws which were in force regulating the traffic in grain, "corners" were not uncommon. He wrote:

> For when you happen to be most in want of grain, they grab it and are unwilling to sell, and you may be well satisfied to buy from them at any price whatever and take your leave of them so that sometimes when there is peace we are reduced to a state of siege by them.

We learn also that the "market masters," who as we have said before had the superintendence of the sale of all other commodities, were not considered sufficient to handle the grain trade also, but

[9] Boeckh, August: "The Public Economy of the Athenians." Tr. by Anthony Lamb. Boston: Little, Brown & Co., 1857. Book 1, Chap. 15.

[10] Lysias: "Against the Grain Dealers." (In Eight Orations of Lysias. Ed. by Morris H. Morgan. Boston: Ginn & Co., 1895. Pp. 89-103). For translation see Botsford, G. W., and E. G. Sihler, "Hellenic Civilization." N. Y.: Columbia Univ. Press, 1915, pp. 426-430.

that "grain inspectors" were appointed for this duty alone and it required fifteen of them to take care of the trade in the city and port of Athens.[11] Being a grain inspector at that time was no sinecure, for Lysias says:

> Ofttimes you imposed upon them, citizens though they were, the most severe penalties, because they were unable to master the scoundrelism of these dealers. What then should the malefactors themselves suffer at your hands, when you even put to death those who are not able to maintain a watch over them.

We learn further that there were "combinations in restraint of trade" at this early date, nearly four centuries before the Christian era, for Lysias says:

> For if you shall find them guiltless when they themselves admit that they made a combination against the importers, you will seem to plot against the skippers who came here.

We also learn that the results of even the most severe punishments, unaccompanied by any constructive substitute for the forbidden practices, were highly unsatisfactory, for Lysias says:

> But it is necessary, gentlemen of the jury, to chastise them not only for the sake of the past, but also as an example for the future; for as things now are they will be hardly endurable. And consider that in consequence of this vocation very many already have stood trial for their life; and so great are the emoluments which they derive from it that they prefer to risk their life every day rather than to cease to draw from you unjust profits. And indeed, not even if they entreat you and supplicate, would you justly pity them, but much more rather the citizens who perished on account of their wickedness, and the importers against whom they made a combination. . . . If then you shall condemn them, you shall act justly and you will buy grain cheaper; otherwise dearer.

Rome: 301-361 A. D.

Rome, not having had the foresight to prevent it, found herself confronted at the close of the third century of the Christian era with a condition of high prices which was very menacing. Diocletian, with characteristic vigor, proceeded to correct this condition by laws and issued his famous Edict in 301 A. D. Abbott[12] tells us:

> In his effort to bring prices down to what he considered a normal level, Diocletian did not content himself with such half measures as we are trying in our attempts to suppress combinations in restraint of trade, but he boldly fixed the maximum prices at which beef, grain, eggs, clothing and other articles should be sold, and prescribed the penalty of death for any one who disposed of his wares at a higher figure.

[11] The population of the whole of Attica at this time was about 500,000, of which Athens comprised about 180,000.

[12] Abbott, Frank Frost: "The Common People of Ancient Rome." New York: Scribner, 1911. Pp. 150-151.

Prices are specified for between seven and eight hundred different items—practically all the articles which his subjects would have occasion to buy. Wages also are fixed—teachers, advocates, bricklayers, tailors, weavers, physicians—all are included. "The carpenter and joiner are paid by the day, the teacher by the month, the knife grinder, the tailor, the barber by the piece and the coppersmith according to the amount of metal which he uses." Abbott calls attention to the fact that the prices given in the Edict are not normal but maximum. As the prevailing prices were so high, however, it is not probable that the maximum prices differed very greatly from them. The net result was failure, and the law had to be repealed because of its impotence in correcting the condition of affairs. Lactantius[13] in 314 A. D. writes as follows of Diocletian and his Edict:

> After that the many oppressions which he put in practice had brought a general dearth upon the empire, then he set himself to regulate the prices of all vendible things. There was also much blood shed upon very slight and trifling accounts; and the people brought provisions no more to markets, since they could not get a reasonable price for them; and this increased the dearth so much that at last after many had died by it, the law itself was laid aside.

The historian Gibbon[14] tells us that sixty years after Diocletian's effort to control the cost of living by fixing prices, the Emperor Julian made a similar attempt, with no greater success. He writes:

> The inclemency of the season had affected the harvests of Syria; and the price of bread in the markets of Antioch had naturally risen in proportion to the scarcity of corn. But the fair and reasonable proportion was soon violated by the rapacious arts of monopoly. In this unequal contest, in which the produce of the land is claimed by one party as his exclusive property; is used by another as a lucrative object of trade; and is required by a third for the daily and necessary support of life; all the profits of the intermediate agents are accumulated on the head of the defenseless consumers . . . When the luxurious citizens of Antioch complained of the high price of poultry and fish, Julian publicly declared that a frugal city ought to be satisfied with a regular supply of wine, oil and bread; but he acknowledged that it was the duty of a sovereign to provide for the subsistence of his people. With this salutary view, the emperor ventured on a very dangerous and doubtful step, of fixing by legal authority the value of corn. He enacted that in a time of scarcity it should be sold at a price which had seldom been known in the most plentiful years; and that his own example might strengthen his laws, he sent into the market four hundred and twenty-two modii, or measures, which were drawn by his order from the granaries of Hierapolis, of Chalcis and even of

[13] Lactantius, L. C. F.: "A Relation of the Death of the Primitive Persecutors." Written originally in Latin. Englished by Gilbert Burnet, D.D. Amsterdam: 1687. Pp. 67-68.

[14] Gibbon, Edward: "The History of the Decline and Fall of the Roman Empire." N. Y.: Fred de Fau, 1906. Vol. 4, pp. 111-112.

Egypt. The consequences might have been foreseen and were soon felt. The imperial wheat was purchased by the rich merchants; the proprietors of land, or of corn, withheld from that city the accustomed supply; and the small quantities that appeared in the market were secretly sold at an advanced and illegal price.

Thus ended Julian's attempt to arbitrarily fix prices. It should be noted that both in the case of Diocletian and Julian the effect of the price fixing was the withholding from the market of the needed food, making necessary the abrogation of the laws by which the prices were fixed.

Great Britain: 1199-1815[15]

Litman[16] in his "Prices and Price Control in Great Britain and the United States during the World War" tells us that "an attempt to control both the wholesale and the retail price of wine by fixing a maximum was made by the British Government in 1199. The measure failed, and in 1330, after a long period of ineffectiveness, a new law was passed which required the merchants to sell at a 'reasonable' price, the latter to be based on import price, plus expenses. This new measure of control proved as futile as the old one."

The first attempt to regulate the price of wheat and bread was made in 1202. The most important ordinance on the matter was 51 Henry III. This ordinance fixed changing weights for the farthing loaf to correspond to six penny varieties in the price of the quarter of wheat from 12 pence to 12 shillings. The law was enforced locally on sundry occasions, but fell gradually into disuse.

Not until 1815, however, were the last laws fixing the price of bread repealed, after a continuous existence of five and a half centuries. The official document [17] recommending their repeal enumerates the ways in which these laws have worked out to show that their repeal is in the interest of the public welfare.

The Dutch Republic: 1584-85

John Fiske[18] in one of his essays ascribes the downfall of the

[15] The English corn laws from 1804 to 1846 furnish probably the best known instance of governmental attempts to stabilize prices in more modern times. The corn statutes of these years are simply a record of the impotence of legislation to maintain the price of a commodity at a high point when all of the natural economic forces in operation are opposed to it. *Encyclopedia Brit.*, 11th ed., Vol. 7, p. 177.

[16] Litman, Simon: "Prices and Price Control in Great Britain and the United States during the World War." N. Y.: Oxford Univ. Press, 1920.

[17] Great Britain, Parliament, House of Commons: Report from the committee of the House of Commons on laws relating to the manufacture, sale and assize of bread. 6 June, 1815.

[18] Fiske, John: "The Unseen World and Other Essays." Boston: 1904. p. 20.

Dutch Republic in 1585 to the bungling price-fixing legislation of the government. He says:

The turning point of the great Dutch revolution, so far as it concerned the provinces which now constitute Belgium, was the famous siege and capture of Antwerp. The siege was long and the resistance obstinate and the city would probably not have been captured if famine had not come to the assistance of the besiegers. It is interesting to inquire what steps the civic authorities had taken to prevent such a calamity. Finding that speculators were accumulating and hoarding provisions in anticipation of a season of high prices, they affixed a very low maximum price to everything which could be eaten, and prescribed severe penalties for all who should attempt to take more than the sum by law decreed. The consequences of this policy were twofold. It was a long time before the Duke of Parma who was besieging the city succeeded in so blockading the Scheldt as to prevent ships laden with eatables from coming in below. Corn and preserved meats might have been hurried into the beleaguered city by thousands of tons. But no merchant would run the risk of having his ships sunk by the Duke's batteries merely for the sake of finding a market no better than many others which could be reached with no risk at all. The business of government is to legislate for men as they are, not as it is supposed they ought to be. If provisions had brought a high price in Antwerp they would have been carried thither. As it was the city by its own stupidity blockaded itself far more effectually than the Duke of Parma could have done.

In the second place the enforced lowness of prices prevented any general retrenchment on the part of the citizens. Nobody felt it necessary to economize. So the city lived in high spirits until all at once provisions gave out and the government had to step in again to palliate the distress which it had wrought.

In this way a bungling act of legislation helped to decide for the worse a campaign which involved the territorial integrity and future welfare of what might have become a great nation performing a valuable function in the system of European communities.

India: 1770 and 1866

The famines of India are prominent features in her history. William Hunter[19] in his remarkable book entitled "Annals of Rural Bengal" writes:

Lower Bengal gathers in three harvests each year; in the spring, in the early autumn, and in December, the last being the great rice crop, the harvest on which the sustenance of the people depends. The December crop failed utterly in 1770 and fully a third of the population died. This disaster stands out in the contemporary records in appalling proportions. It forms indeed the key to the history of Bengal during the succeeding forty years.

In 1770 the government by interdicting what it was pleased to term the monopoly of grain, prevented prices from rising at once to their natural rates. The province had a certain amount of food in it and this food had to last nine months. Private enterprise if left to itself would have stored up the general supply at the harvest with a view to realizing a larger profit at a later period in the scarcity.

[19] Hunter, William W.: "Annals of Rural Bengal." Ed. 7. London: Smith, Elder & Co., 1897.

Prices would in consequence have immediately risen, compelling the population to reduce their consumption from the very beginning of the dearth. The general stock would thus have been husbanded and the pressure equally spread over the whole nine months instead of being concentrated upon the last six. Instead of this the government in 1770 prohibited under penalties all speculation in rice. A government which in a season of high prices does anything to check speculation acts about as sagely as the skipper of a wrecked vessel, who should refuse to put his crew upon half rations.

Very different was the procedure of the government at the time of the famine of 1866. Far from trying to check speculation, as in 1770, the government did all in its power to stimulate it. In the earlier famine one could hardly engage in the grain trade without becoming amenable to the law. In 1866 respectable men in vast numbers went into the trade; for the government by publishing weekly returns of the rates in every district rendered the traffic both easy and safe. Every one knew where to buy grain cheapest and where to sell it dearest and food was accordingly bought from the districts which could best spare it and carried to those which most urgently needed it.

In 1770 the price of grain, in place of promptly rising to three half-pence a pound, as in 1865-66, continued at three farthings during the earlier months of the famine. During the latter months it advanced to two pence, and in certain localities reached four pence.

Colonial United States: 1633-1779

Passing now to the eighteenth century some observations will not be amiss on the price-fixing measures resorted to in our country during Colonial days and the early years of the Republic, and also in France during the tragic period of the French Revolution.

Both of these periods have been so ably described that little seems necessary except to give the references to the literature. Winthrop[20] tells us, in 1633:

> The scarcity of workmen had caused them to raise their wages to an excessive rate, so as a carpenter would have three shillings the day, a laborer two shillings and six pence, etc.; and accordingly those who had commodities to sell advanced their prices sometimes double to that they cost in England, so as it grew to a general complaint, which the court, taking knowledge of, as also of some further evils, which were sprung out of the excessive rates of wages, they made an order that carpenters, masons, etc., should take but two shillings the day, and laborers but eighteen pence, and that no commodity should be sold at above four pence in the shilling more than it cost for ready money in England; oil, wine, etc., and cheese, in regard to the hazard of bringing, etc., (excepted).

Bolles [21] gives an excellent account of the experiment of price-fixing in the early years of the United States in the attempt to stop the rise in price of the necessities of life, caused by the declining value of continental paper currency.

[20] Winthrop, John: "The History of New England from 1630-1649." Boston: Phelps and Farnham, 1825. Vol. 1, p. 116.

[21] Bolles, Albert S.: "The Financial History of the United States from 1774-1789." Fourth ed. New York: D. Appleton, 1896. Pp. 158-173.

Pelatiah Webster[22] discusses the legal limitation of prices with vigor and lucidity and shows by resistless logic that such legislation defeats its own end in several ways, the most important of which is the withholding of commodities from the market which it inevitably produces.

On December 20, 1777, Sir Henry Clinton, in charge of the British forces occupying New York, made a proclamation[23] as follows:

> Whereas it is consonant not only to the common principles of humanity but to the wisdom and policy of all well-regulated states, in certain exigencies, to guard against the extortion of individuals, who raise the necessaries of life, without which other parts of the community can not subsist; and whereas the farmers in Long Island and Staten Island are possessed of great quantities of wheat, rye and Indian corn for sale, beyond what they want for their own consumption; and it is highly unreasonable that those who may stand in need of those articles should be left at the mercy of the farmer; and whereas it is equally just and reasonable that every encouragement should be given to the industry of the husbandman, and that in all public regulations respecting the price of the produce of his lands, regard should be had to that of the conveniences which he is obliged to purchase, and whereas the present rates at which wheat, flour, rye meal and Indian meal are sold, do vastly exceed in proportion the advance price of those articles which the farmer stands in need of purchasing, and I being well satisfied, from the best information, and most accurate estimates, that the following prices upon the articles above mentioned will be liberal and generous, have thought it fit to issue this Proclamation, and do hereby order and direct that the prices to be hereafter demanded for the said articles shall not exceed the following rates, viz.:
>
> A bushel of wheat, weighing fifty-eight pounds, twelve shillings, with an allowance or deduction in proportion for a greater or lesser weight. A bushel of rye or Indian corn, seven shillings, etc.

The proclamation proceeds to state that the farmer shall declare how much grain he has and if he presume to sell for a higher price than the one stipulated or "refuse to sell the same at those prices, shall be subject to have his whole crop of grain, or quantity of flour or meal, concerning which such offence shall happen, seized and confiscated, and himself liable to imprisonment for such offence."

Davis,[24] in his able and comprehensive treatment of limitation of prices in Massachusetts, gives much information relating to this

22 Webster, Pelatiah: Political Essays. Philadelphia: Joseph Cruikshank, 1791. Pp. 11-18.

23 Clinton, Sir Henry: Proclamation, Dec. 20, 1777. (In the Remembrancer; or Impartial Repository of Public Events. Ed. by John Almon. London (Vol. 6): 1778. Pp. 57-58).

24 Davis, Andrew McFarland: "The Limitation of Prices in Massachusetts, 1776-1779." (In Colonial Society of Massachusetts Publications, Vol. 10. Boston: 1907. Pp. 119-134).

subject in the other states also. Felt[25] gives extracts from the text of the "Act to prevent monopoly and oppression." He also gives the actual prices set for the various commodities, and in appendix 2 gives "prices of grain, etc., appointed by the general court and taken as currency." These prices are of much interest as they go back to 1642 and were legal tender at that time.

Weeden[26] writes in his "Economic and Social History of New England, 1620-1789":

> The colonial history of the United States affords many instances of the failure of fixed prices to remedy the evils they were designed to cure. The governor and council of New England fixed the price of beaver at 6s in fair exchange for English goods at 30 per cent. profit, with the freight added. The scarcity of corn which was selling at 10s "the strike" led to the prohibition of its sale to the Indians. Under the pressure of this prohibition the price of beaver advanced to 10s and 20s per pound, the natives having refused to part with beaver unless given corn. The court was obliged to remove the fixed rate and the price which ruled was 20s. An equally fruitless attempt was made to regulate the price of labor. These regulations were inforced for about six months and then were repealed.

France: 1789-1793

As regards the limitation of prices in France during the Revolution, there seems nothing to add to Bourne's[27] discussion of this subject in the *Journal of Political Economy* for February and March, 1919. We can not fail to note, however, that the system failed signally in France as elsewhere, because supplies were withheld from the markets. The producers could not be forced to declare what they had and without this knowledge the government could not prosecute for withholding them. Bourne writes:

> The arguments in the convention relative to the matter ran the whole gamut from the principles of economic liberty advocated by the economists of the day to the radical abstractions of Robespierre and his followers, who swept commerce aside by maintaining that "The food necessary to man is sacred as life itself," and "The fruits of the earth like the atmosphere belong to all men."
>
> One of the most interesting of the many suggestions made in the convention was that of Barbaroux who advocated "a plan to form local associations to collect and circulate information about the crops. In other words, for coercion he would substitute cooperation, believing that the French citizens, farmers and merchants included, would not turn a deaf ear to an appeal for common action against the oncoming peril" (famine). Price fixing finally

[25] Felt, Joseph B.: "An Historical Account of Massachusetts Currency." Boston: Perkins and Marvin, 1839. Pp. 170-173, 184-185, 242-245.

[26] Weeden, William B.: "Economic and Social History of New England, 1620-1789." Houghton: Boston, 1890.

[27] Bourne, Henry E.: "Food Control and Price-fixing in Revolutionary France." (*Journal of Political Economy*, Vol. 27, pp. 73-94, 108-209. February and March, 1919).

became one of the characteristic features of the Reign of Terror, and when Robespierre and his councilors passed through the streets of Paris in the carts of the executioners the mob jeered saying, "There goes the dirty maximum."

SUMMARY

The history of government limitation of price seems to teach one clear lesson: that in attempting to ease the burdens of the people in a time of high prices by artificially setting a limit to them, the people are not relieved but only exchange one set of ills for another which is greater. Among these ills are (1) the withholding of goods from the market; (2) the dividing of the community into two hostile camps, one only of which considers that the government acts in its interest; (3) the practical difficulties of enforcing such limitation in prices which in the very nature of the case requires the cooperation of both producer and consumer to make it effective.

Egypt took entire control of the grain trade and saved the people from starvation, but took over the land in return.

China worked out a system of control of supply and demand which kept prices normal. She seems to have been the only country which recognized the whole price question as being a symptom and not the disease itself, and because she recognized this fact seems to have come nearer than any other country to solving the problem of supplying the people with the food they needed at a price they could pay.

Athens regulated the grain trade and set prices by legal enactment, but found herself unable to enforce them.

Rome made a colossal experiment in controlling prices by legal enactment, but it utterly failed.

Great Britain had on her statute books laws fixing the price of bread continuously for more than 500 years. The price of wheat, fish and wine was also regulated, but all such laws were abrogated in 1815, because of their failure to accomplish the purpose for which they were designed.

The Dutch Republic was overthrown in 1585, and at least one historian of note declares that price-fixing legislation was largely responsible for its downfall.

India has learned in the hard school of experience that even in times of famine price fixing is a very dangerous expedient because it removes one of the most powerful checks on consumption, namely, high prices.

The Colonial United States tried the same experiment at various places and times but failed utterly to secure satisfactory results.

Revolutionary France tried the same measures, but the protagonists of the movement perished on the guillotine. The dreary story of France's efforts to limit prices is distinguished from that of the other countries we have noted because of the proposal of Barbaroux to enlist the aid of both producer and consumer in the effort of the government to control the food supply in the interest of the people's welfare. This proposition was not carried out but it furnished the first indication of the goal of cooperation toward which we are still pressing.

THE SCIENCE OF HERODOTUS[1]

By JONATHAN WRIGHT, M. D.
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THERE is an ever-recurring obscuration of the meaning of words as soon as there is much discussion focussed on the conceptions for which they severally stand. One of the most glaring instances of it in modern times is the word history. Two schools of historians some few years back, a decade or two perhaps, fell foul of one another as to just how it should be written. They belabored one another with great fury and, though I don't think it was ever mentioned by either party, it became evident to dispassionate spectators, beyond the pale, that there should be a differentiation of terms. One school should be called annalists, almanac makers Boswell called them in controversy on the subject with Dr. Johnson, and the other school should be known as excursionists, or if there were such a word, "discursionists." Of course the thought occurs to the Spencerian philosopher that here is the law of the evolution of thought in action. Here is differentiation, here is an evolution from the homogeneous to the heterogeneous and we naturally say the history of science is simply a specialty. Naturally too, this time with a little tone of irritated defiance, we declare that scientific methods of writing history must prevail in the history of science. But is this all just so? In the first place the lay historian is at once in revolt. He wants to know which one is to be called the School of History. The man outside the pale makes a hasty retreat, muttering "bigotry, intolerance, nonsense." And the man of science loftily says, "merely an evolutionary phenomenon."

It is quite evidently then not so simple as any of these formularies might lead us by inference to believe. The question arises, Is history literature? Well, one can not be an annalist or an almanac maker type of historian without feeling in duty bound to answer, " Not exclusively," but if he wishes to exclude the "discursionist" he plumply says "Not primarily." Then he has to compromise and amend by adding, not necessarily. Back of all this contention for the name of historian lies the desire of the annalist

1 References are to the text of Herodotus. Herodoti historiarum, libri IX, ed. H. R. Dietsch (Teubner).

for readers. This is pressing for the lay historian. It has been demonstrated that men of science can be content to be almanac makers despite the knowledge that no one reads an almanac, but the lay historian has been forced to admit that history is literature, a part of it anyhow, whether he is an annalist or a "discursionist." It is founded on the fact that the knowledge of history forms a part of education that the liberal conception of the latter calls for the diffusion of knowledge as well as its revelation, and on this they base their excuse for bidding for readers. A history that is not read, whether it be of science or of comedy, falls so far short of any one's conception of history that there would seem to be little left to discuss as to who are historians and who are not. To avoid any further reference to it I may explain at once that under the category of almanac makers I meant to range the paleographers and archivists, the pure researchers of history, who make no pretence and have no claim to belong to literature at all. There is plenty to say for them, as much as for the monks and fanatics of all sorts who have or believe they have a grasp on facts and realities that entitles them—and they are right, it does entitle them—to be ranked among the benefactors of the human race. If they really insist that to them and them only belongs the title of historian, I for one out of pure gratitude will gladly serve on a committee to elect some new term to include the "discursionist" in the ranks of those whom we have to call historians, for how are we going to shut Herodotus out? How are we as researchers of science, turned historians, going to justify ourselves for cutting ourselves off from the reading public? The public doesn't read the best literature, it is true; they read poor literature, but poor literature even would soon perish from the world if it were not an humble stepping stone to good literature. Destroy the Queen of the Hive and there are no more bees. Whether it is good literature or bad literature, how is the historian of science to take his important part in any scheme of education unless he reaches the average man of science, the man of science in the street, unless he writes some kind of literature, good or bad, which *attracts?*

It is true that one need not be an excursionist to attract. Thucydides was no excursionist, surely not a "discursionist," and when we read Herodotus and Thucydides we perceive the schismatic feuds of the historians in our day really began with them. We see it is not so much a phenomenon of cultural evolution as an example of two ways of arriving at the same end—the arrest of the attention of busy men long enough at least to instil into their minds something they much need.

All that is good in either method enters by right into any

scheme of education, but the writer who takes no care to attract, makes no effort to allure readers, does not belong to it at all. Charles Booth, the greatest benefactor of humanity, the greatest propagandist of the faith in the 19th century, shrewdly said he did not know why the devil should have a monopoly of the best tunes—those that most move the minds of men—and there is no reason why the propagandists of science should not fall in line with what the minds of men crave as well as the Salvation Army.

I can not linger to point out how these archetypes of the modern genus historian differ, but as between the Prince of Annalists and the Prince of Excursionists, Science can not be long in choosing. Meager indeed are the facts the modern man of science can glean from the fascinating pages of Thucydides, but in those of Herodotus even the modern ethnologist and anthropologist will find information worthy of his attention. Geography and geology quite evidently occupied the thoughts of thinking men of the golden age of Greece. It is not only biology and physiology and climatology which may receive hints from his discourse, but more than all, ethics and the science of moral philosophy, the wisdom of the world, that which is science but vastly more than science, forms a veritable mine open to him who meets it with an open mind. If the historian tells us this is not history, these are excursions and diversions, let us not for a moment imagine that they are not history for the historian of science. We can afford to let the ever smouldering feud go on in lay circles as to whether this thing is and that thing is not history; if the Father of History is no father of theirs, we can only think of the wisdom of the child in recognizing his male parent, which some historians of a recent day do not possess. It is these very excursions, this very discursiveness, the digressions from the path of the story, almost unknown in the tense, vivid pages of Thucydides, which give value to the books of Herodotus as a source for the history of science. These are the things which are history for us and these are the things which, by virtue of their attraction to all men as resting places, if as nothing else, have preserved to us the work of Herodotus for more than two thousand years. Not these diversions alone but pure gossip and idle tales coax the footweary along the central highway. Primitive man is incapable of any other kind of journeys into things intellectual. Assiduity and concentration of mental efforts and, of all things, persistence and patience are acquired virtues and fundamentally that is the reason the pages of Herodotus have been preserved to us and have preserved their charm for the children of primitive men to this day. It is after all the natural way to acquire knowledge. Man picks up most copiously and most to his

advantage those things he absorbs incidentally as he moves to other destinations.

I shall elsewhere have an opportunity to show that Herodotus deliberately and as a matter of art adopted this discursiveness into gossip and tales from the Arabian Nights, but he had no idea that he was departing at all from the true functions of history in his discourse on the geology and cosmogony of Egypt or on the ethnology of the tribes that trooped along behind Xerxes and his Medes and Persians into Greece from all, even the remotest corners, of the known world, perhaps even not when he relates[2] that in Libya lambs come forth at once horned. He shades the phrase just enough not to assert they are born with horns but allows the reader to join with him in the doubt whether or not the genital canal of the mother is in danger of laceration from her offspring. We however forgive the inexactitude of statement when he takes up the discussion of the seasons for this precocity in sprouting horns. He suggests that in these warm climates they grow more quickly. In rigorous climates of severe cold the cattle at first either do not grow horns at all or grow them with difficulty. For my part as a reader of history I halt with pleasure from the bloody murderings of savage men and the sordid rascalities of ancient politicians. It is a digression that rests me and informs me and pleases me, because in this epoch when an era of biological theory has closed and another one has been ushered in, when evolutionary theories are fighting desperately for survival, it brings to my consciousness that man was busy with such thought at the dawn of written records. Apparently Herodotus thought it a legitimate digression. When however he turns to mules he does apologize for the digression. They are so different from lambs, I suppose, but he apologizes in a way that shows these digressions, as I have said, are a part of the art of history writing for him. "The plan of my work from the beginning has sought digressions," he says in parenthesis.

I desire also to show that he grouped all such phenomena in an etiology of environment. He breaks into his story of the northern people with an animadversion to the Libyan phenomenon. Then he switches back to the Chersonese again as though the mule observation reminded him of another example elsewhere ranged under the same law. "I wonder," he says, "that in the whole territory of Elea they can not breed for mules, the climate being neither cold, nor any other cause to account for it," and then he tells what the Eleans themselves say, which is trivial, but the passages allow us to see how the climate as an etiological factor lingers in his

[2] IV, 29.

mind as it did in that of Hippocrates, and caused him to write the wonderful book on climates—Airs, Waters and Places. They were both but voicing the thought of their time. Again it recurs in Herodotus.[3] The Persians, modern archeological criticism has fairly well shown, were descended from northern people, come down to territories below the Caspian Sea evidently from around the eastern end of the Black Sea, more than a thousand years before the time of Herodotus perhaps, on their way to India. The Medes and the Persians stayed behind in a temperate climate and by the time of Xerxes they ruled the tropical tribes of Africa and India and many others and Xerxes laid his conscription on them all and led the most heterogeneous levy of men ever marshalled under one command across the Hellespont. But long before these events there occurred a battle in Egypt between the forces of the Persian King Cambyses, led by the Greek renegade Phanes, and the Greek auxiliaries aiding the Egyptians who were put to flight. This battlefield, some seventy years afterwards perhaps, Herodotus viewed: "I saw a wonderful sight which the people dwelling near told me of. The bones of the Persians lay separately in one place as they stood separately in the battle; elsewhere were the bones of the Egyptians. The skulls of the Persians were so weak that if you struck them once with a stone you would make a hole in them, but the skulls of the Egyptians were so strong you could hardly burst them pounding them with a stone." The old jokes about the thickness of the negro's skull used to pervade the minstrel shows of my youth. Perhaps one can occasionally find them in the funny columns of the newspapers now, but I have really forgotten whether modern anatomical science has given its countenance to them, though I am under the impression that it has. At least modern archeology has shown how large a mixture of pure negro blood there was in the ancient Egyptians. If the joke was of hoary antiquity in Herodotus's day, how modern is his discussion of it! He says this marvel he saw himself, so evidently he was not acquainted with the end man's jibes and repartees and therefore perhaps he was the first to contribute this observation to biological science. The etiological theories of his day may not all of them be admitted to be legitimate claimants to a place in modern discussions, but orthodox or heretical as it may seem to one or the other of modern disputants there is no doubt of the modern plausibility of the one Herodotus chose to transmit to us as the one he thought most reasonable.

"They say the cause of this is, and I readily believe them, that the Egyptians from their childhood up shave their heads and

[3] III, 12.

the bone"—(mark the singular, not the "bones")—"is thickened in the sun. This it is and not because they are bald (naturally) for any one may see that the Egyptians are the least bald of all men. This is the reason the thick skulls belong to them, and as for the Persians, this is the reason they have weak skulls—they grow up in the shade wearing woolen tarbooshes. These things I saw there and others like them I saw at Papremis in those perishing with Achaemenes, the son of Darius, at the hands of Inarus, the Libyan."

Now the battle in which Phanes saw his children sacrificed before his eyes, and Papremis also, may have been great battles, but Herodotus was unconsciously formulating the grounds of a discussion from which in the last hundred years have arisen conflicts, doubtless not so bloody, but not inferior in ardor nor lacking in acrimony and vastly more persistent. Is it the primeval unvarying germ plasm of the negro race or the sun that curls their hair and thickens their skull? Is it climate that starts the lambs' horns to growing in utero? Has not the climate something to do with success in mule breeding? Have we arrived at a satisfactory understanding of the influence of environment on the heredity of man or beast? Those skulls lay heavy on Herodotus's mind, when he spoke of the "bone" of the skull, for he knew well there was more than one usually. He remarks[4] that at the battle of Platæa a Persian fought, whose skull was all one piece of bone, gums and teeth making a solid continuity. The man was five cubits high (7½ ft.?). Aromegaly? I am not an anatomist or pathologist enough to know what it was Herodotus marvelled at, but there can be no doubt he was an acute observer, and a more competent reader than I, if he comes to be as sympathetic toward Herodotus as I am, will easily be able to tell what lesions of giantism confronted him. Elsewhere he several times alludes to the giant stature of individual Persians, some of them, I think, a little exceeding five cubits, but nothing unbelievable in this connection. In these citations of his contributions to this early discussion of evolutionary points I can go no further, nor can I linger long in the few other fields I shall venture to touch upon. I can only seize upon a few of the phenomena Herodotus was interested in, more especially those which lend themselves most readily to a transportation to modern attention. Many fields I have not entered at all here, to which the historian of science may revert with profit.

It is, however, in other fields of science that Herodotus has made the most valuable contributions to its history. These are especially marked in ethnology and to a certain extent they have

[4] IX, 83.

been utilized by some writers, but although much has been left which has not become current knowledge among intelligent men of science I shall not be able more than to touch upon even the ethnology here, and that incidentally to other interests. The question as to how much of the knowledge, lodged in the motley nations of men who dwelt in the basin of the Mediterranean, had been derived from the inhabitants of the hinterland is a matter of great interest. On the whole it has been minimized, I think, rather than magnified by modern writers. Everything which modern historical research has revealed goes to prove how just was Herodotus's conclusion that the garden lands around the Mediterranean were being constantly repeopled or rather their peoples were being constantly replenished by the pressure of Scythian tribes in the hinterland, and they in their turn were being pushed down by the Hyperboreans.[5] Of these surprisingly little was known by Herodotus, but it is surprising only in view of his remarks on the mighty host who crossed the Hellespont with Xerxes. No reader can help being moved at the panorama, revealed to us by the Father of History, which stretched out at the feet of the Persian monarch. If Xerxes wept it probably was not so much at the thought they would all be dead in a hundred years, but from a natural emotion, though not altogether an easily defined one, at the spectacle of the throngs of mankind from every known region of the world arrayed under his banners along the shores of the Chersonese which are washed by the Sea of Marmora, where men are still battling for much the same reason that he was leading his myriads into Greece. Of all these Herodotus has something to say and no one can fail to appreciate that ancient knowledge of the tribes of mankind was far from inconsiderable, but it was the acquaintance with the tribes of the regions south and east of the shores of the middle sea that was by far the most extensive. Modern ethnology is continually having revealed to it that the statements of Herodotus as to these are not wide of the mark, forming a most curious and instructive contrast with the trash collected in the volumes of Pliny—a contrast continually intruding on us when we compare the culture of Greece with the bastard civilization of Rome.

Even of far India we get confirmation of his cannibal story from a source two thousand years later. He says[6] the Hindus, living in the far east are nomads and eat raw flesh and kill their relatives before age or disease has spoiled their flavor, accounting it a piety by thus absorbing them to save them from the sorrows and trials and sufferings of this world. Ludovici Varthema, we

[5] IV, 16.
[6] III, 99.

are told,[7] foremost of travellers and adventurers in the 16th century (A. D.), sailing from Bologna, visited Java and brought back the same account. When Sataspes, at the behest of Xerxes, as a punishment for a profligate Persian nobleman who had committed rape on a noble woman, sailed past the Pillars of Hercules and out into the northern ocean he turned south to circumnavigate Africa; the reward he was to receive for accomplishing it was his life. He failed, returned and was impaled. Sailing for months and months to the south down the west coast of Africa he came off shore alongside of some small people clad in garments of palm leaves, who when he came toward them in the ship fled to the mountains. There can be little doubt from Herodotus's account[8] that in his day the pygmies, in whom the world disbelieved for twenty-five hundred years—even after Du Chaillu found them in Central Africa—dwelt by the sea. Necho, king of the Egyptians, had sent the Phoenicians around Africa sailing out of the Red Sea to the southern ocean and then by the north ocean through the Pillars of Hercules to the Mediterranean ports of Egypt. Much of Asia was explored under the orders of Darius the Great, who ascended the throne of Persia about the time Herodotus was born or a little before. He wanted to know something of the Indus and sent Scylax of Caryander to investigate its mouths where it enters the sea. He and his comrades went down the river and sailed across the Arabian gulf, up into the Red Sea to the starting point whence, some hundred and forty years before, the Phoenicians set out for the circumnavigation of Africa at the command of Necho, so it is not difficult to credit the knowledge of Herodotus to the Egyptians and to the enterprise of the great Persian monarchs, so far as his geography and his ethnology are concerned.

"As to this country (of Egypt)," he says, "much of it, according to what the priests tell me, and it seems to me myself to be so, is land which has been a gift to the Egyptians. It appeared to me that the space above Memphis in between the mountains I have spoken of had been a gulf of the sea, just like the plain around Ilion and Teuthrania and Ephesus and the plain of the Meander, if one may compare these small examples with this huge one. For, their rivers also by silting up having formed these territories, not one of them as to extent can be compared to a single mouth of the Nile, and of these there are five. There are other rivers also, not like to the Nile as to size, which show evidence of the great changes they have brought about. Of these I can give the names and not the least of them is the Achelous running through Akarnania and

[7] Boulting, William: Four Pilgrims, N. Y., Dutton, 1922.
[8] IV, 42, 43, 44.

emptying in the sea, which has made a mainland out of the islands of the Echinades," where Missolonghi is now situated on the Ionian Sea. "There is also in Arabia a territory not far from Egypt, a gulf of the sea jutting into it from what is called the Red Sea, long and narrow, as I am about to relate. The sailing distance, starting from the upper end down to the broad sea takes forty days to cover in a boat manned by oars, but the width of the gulf at its broadest is only half a day's sail. There is flood and ebb tide in it every day. I think once there was another gulf and this an Egyptian one somewhere which set in from the northern sea(Mediterranean) toward Ethiopia; that from the south jutting in towards Syria I have just spoken of. Ends of these had bored through towards one another so as almost to meet, but turning aside a little in the interior of the land. If therefore one wished to divert the current of the Nile into the Arabian Gulf what would hinder it from setting up a barrier in the course of twenty thousand years? I should think it might be raised in ten thousand years. Somewhere within this past time before I was born, would not the gulf silt up and much more, the river being such a hard working one in this way? I follow the opinion of those speaking thus concerning Egypt and I am very much of that opinion myself, having seen a part of Egypt extending beyond its contiguous territory showing shells upon the hills and sea salt spread on the surface, so that the pyramids suffer, and the sand alone making a hill above Memphis and in this place Egypt being like neither Arabia or Lybia and not like Syria for that is a part of Arabia in which the Syrians dwell."

It is probable that when the Athenian in Plato's dialogue of The Laws declared (II:656) that the arts of life had existed ten thousand years in Egypt he was giving vent to a credulity much greater than that of Herodotus, for the existence of civilization is a very different thing from the existence of the life of man in the delta of the Nile. To strengthen their hold on the social organization fast crumbling to annihilation of the empire before the days of Herodotus, the priests of Sais and of Heliopolis manufactured fictitious chronology very evidently, but geologists of more recent date, of the most recent indeed, have brought the figures the priests suggested to Herodotus within the margin of error which is even at present inevitable. So when Herodotus remarks that these priests of Sais were the most learned men he had ever met, those knowing most of the past history of world events, we may be ready to believe that the science they possessed and which he transmits to us represents no negligible body of knowledge existing at the dawn of written records.

Every once in a while, in journals like the SCIENTIFIC MONTHLY, we get a résumé of the state of geological knowledge in refutation of the story Plato tells in the Timæus as to the lost continent Atlantis. I think the preponderance of this geological opinion is to the effect that there are more reasons to believe it never existed and never sank beneath the waters of the ocean in a mighty cataclysm of nature, that like some of the chronology of the priests of Sais the story of the Atlantis was purely fictitious. According to this it wrought havoc with geography not only far out into the Atlantic but it split the rocks of the Acropolis at Athens and altered the shores of the Mediterranean thereabouts. The preponderating view of the geologists is well set forth in a condensed and non-technical form in a publication[9] of the American Geographical Society of recent date. It is only somewhat less frequently than the refutation there arises some one from the ranks of science to give expression to his belief that the story was founded on a tradition having its origin in some such cataclysmic event. Doubtless the conviction which has gathered strength of recent years that the last ice age, both in Europe and in America, was very much more recent than was believed generally by cosmologists a generation or so ago, has had a stimulating effect on the tendency to find the tale from the Timæus creditable as being founded on geological fact. The dates given by Plato not varying much from those given by Herodotus and confirmed by modern science for the approximate age of the delta of the Nile can not fail to suggest that there was prevalent in Greek science a well-founded belief in this cataclysm. Herodotus lived into the age of Plato and read his histories in Athens and doubtless Plato was familiar with them and there could not have failed being an affinity of relationship between the theories as to the Nile and of that as to the sunken continent. Ten or twelve thousand years before the age of Pericles, it must have been thought there was a different course of the Nile and a huge island or continent outside the Pillars of Hercules and that some cosmic disturbance, wide extending and deep reaching, had brought about the geography of the Nile and the shores of the Mediterranean as we know them.

When the Greek became convinced of the ancient nature of Egyptian civilization and saw the evidence of the recent formation of the delta of the Nile, his fertile mind could not fail of being impressed with the dramatic contrast and the probability of a cataclysmic change which not only had once really occurred, but which had given rise to innumerable fables of feats ascribed to the

[9] Babcock, William H.: "Legendary Islands of the Atlantic. A Study in Mediæval Geography," 1922.

gods around the Mediterranean, a suggestion not very happy as to the latter, since primitive man has stocked every corner of the globe with fables. However, it is quite as evident as the recent date ascribed to the last recession of the ice that in a period roughly corresponding to it the Nile, then rolling its fertile floods into some other sea basin, the Arabian Gulf or more probably down the valley of the Congo to the Atlantic, was more or less suddenly checked by some upheaval of terrestrial planes and directed toward the Mediterranean. I do not pretend to any ability to interpret correctly the theories of geologists, but this to the average intelligent man of science of to-day makes a strong appeal, and the facts of history and the fables of antiquity seems to fall in line with it. One can not help being impressed with the coincidence of chronology from so many different sources. What Herodotus says of the land of Egypt, what Plato passes on to us as to the lost Atlantis, the confirmation of Herodotus's report as to the age of the delta of the Nile by modern geology and finally the present advocacy of the recent date for the recession of the ice sheet from temperate European and Asiatic regions—all together they lend an air of probability to the old legend of the Atlantis which has invaded geological opinion itself. Termier's advocacy of it seems well known and recently the article by "Ph. Negris, docteur honoraire de l'Université d' Athénes," in the *Révue Scientifique* for September, 1922, has for its opening phrases the following:

"The tradition of the submersion of the Atlantis has been for a long time relegated to the realm of fables; I shared in this general opinion myself until the American geologists established the time with narrow limits (seven to ten thousand years) which has elapsed since the glaciers have receded."

Then he goes on to set forth in a much more frank and uncompromising way than usual in such articles his belief in the prehistoric existence of the Atlantis and in the general scheme of geological events which accompanied its subsidence into the bed of the Atlantic Ocean. Though he extends the argument far beyond the line possible to an article on the science of Herodotus and his Nile theories, I doubt if geological readers generally, even in this country, will find any new evidence in it, but I instance the article, as I might a number of others, in evidence of the growing interest in phenomena which aroused the same theories in Herodotus and Plato near twenty-five centuries ago, but there exists more to support them in our day than in their own.

CONSCIOUSNESS AND THE SENSE OF TIME

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IN recent decades the progress which has been achieved towards the mechanistic interpretation of life-phenomena has been truly startling in its magnitude. Not only have the more obviously mechanical aspects of life been largely traced to the interaction of physical and chemical factors or analyzed into component parts which may be clearly perceived to originate in physical and chemical phenomena, but even those activities of the higher animals, which we were formerly disposed to attribute to the operation of psychic factors, have been so frequently analyzed into mechanistic components that many biologists are beginning to feel that in the interpretation of life-phenomena psychic factors are wholly superfluous. Thus the tropism theory of Loeb, which reduces the directional or "oriented" reflexes of animals to the operation of asymmetric muscular tensions; the older investigations of Fabre, which showed that the elaborate "instincts" of insects represent so many series of concatenated reflexes, directional or other, each reflex affording the stimulus which awakens the next; the investigations of Pawlow, which have shown that "associative memories" are spatially distributed in the central nervous system of the dog in a fashion which corresponds to the spatial distribution of its skin-receptors; the investigations of Cannon, which have traced the expressions of emotion to the operations of chemical excitors or hormones—all of these and many other investigations unite in eliminating consciousness from the group of factors which we have ascertained to be determinative in animal existence.

Now this is a very strange thing, because it is impossible to postulate mechanism without at the same time postulating a percipient consciousness. It is quite useless to attempt to evade this fact. To wilfully disregard consciousness, as something lying outside the real world of scientific investigation, is not to deprive it of existence. If it is a mere illusion, how shall we trust it to enable us to understand those things which are not illusory? The more perfect our mechanistic interpretation of nature becomes, the more utterly do we rely upon the verity and reality of consciousness. It becomes, in fact, our sole prop and stay.

There have been many philosophers and some biologists who, following the path indicated by Berkeley, have not hesitated to ascribe reality solely to consciousness, so that the whole exterior world is viewed as a complex tissue of states of the percipient consciousness. Mechanism in that case would become identical and coextensive with consciousness. But to this theory there is the familiar answer that there is not only one percipient consciousness, there are many. It is true that we can not directly experience the consciousness of any other individual, and, perhaps, from the point of view of a physiologist, it is conceivable that all other individuals except himself might be successfully interpreted as unconscious automata. But this has never commended itself as a reasonable viewpoint, and it is universally conceded that a legitimate argument from analogy justifies us in assuming the existence of multiple discontinuous consciousnesses.

Furthermore, the fact that our perceptions of the outside world are wholly expressed in terms of states of consciousness (for example, color, which has no existence as such in the physical universe), does not in the least controvert the fact that the exciting cause of these states of consciousness lies outside consciousness itself. In other words, there is a reality without as well as a reality within, so that although the reality within, the subjective real, can not perceive the reality without, yet it can perceive the effects of that outside reality upon itself.

A great many contemporary biologists, perhaps the majority of them, are either tacitly or confessedly "monists" of one variety or another. That is, they believe that the universe is one thing, either matter or some other primal entity comprehending consciousness and matter within itself. It is true that pure materialism leaves consciousness unexplained, while it utilizes consciousness to construct its thesis, so that it is logically indefensible. Psychomonism, as we have seen, lands in less obvious, but not less real absurdities. "Psycho-physiological parallelism" states a fact or an assumption, but leaves the fundamental question of unity or duality without an answer. Nevertheless the hypothesis of monism continues to claim a large number of adherents because it receives very substantial support from two independent lines of reasoning and research, which converge towards the same conclusion.

The increasing insistence upon the importance of "subconscious" mental activities by students of psychology and psychological pathology has inspired a number of contemporary philosophical generalizations, of which Bergson's doctrine of "creative evolution" may serve as a type. These hypotheses emphasize the

importance and value of the instinctive and intuitive states of consciousness at the expense of the ratiocinative. Ethically, such doctrines are capable of being construed in a very dangerous fashion. They commend themselves to those who prefer the rule of impulse and emotion to the rule of reason. They set the archipallium above the neopallium. They render the latest acquisitions of man's evolution useless or positively harmful. They lead us away from occidental thought into the mystical regions of oriental speculation. They constitute a denial of the right of reason to rule and direct, and therefore they cut at the root, not merely of our material progress, but also of our social organization, a fact which anti-social elements have not been slow to grasp.[1] We, that is to say the scientific investigators, who have pinned our faith to the contrary supposition, are therefore entitled to scrutinize very narrowly the assumptions which lie at the foundation of these philosophical ideas, and to inquire whether the facts really compel the deductions which have been so freely and fearlessly drawn from them.

Fundamentally, I believe the chain of reasoning which is held to prove the bankruptcy of reason runs something like this: Observations under hypnosis, and in conditions which are probably allied to hypnosis, have revealed the recoverability of vast stores of memories and experiences, of the existence of which we are normally unconscious. Now, at this point a very natural assumption is made, without which the whole subsequent superstructure of reasoning falls. Since memories are customarily associated in our experience with consciousness, it is assumed that those memories of which we do not possess a *waking* consciousness are nevertheless associated with some different or "subliminal" type of consciousness. Since these memories are demonstrably far more extensive than our "waking" memories, therefore, also, this "subconsciousness" is much more extensive than our waking consciousness, and by a natural association of the idea of capacity with that of potency, it may also be supposed to be more fundamental and more important.

Alone, this argument might have failed to carry conviction to the minds of its originators. It received striking support from a much older school of thought, however, and the coincidence of two arguments sufficed to accomplish that which neither would have been able to perform unaided.

The origin of consciousness has engaged the imagination of philosophers and the more philosophical types of scientific men

[1] Lothrop Stoddard: "The Revolt against Civilization," 1922, p. 162.

from a very remote period of history, and some form of panpsychism, or theory of the universal distribution of consciousness in matter, has been regarded by very many, in every generation since the fifth century B. C.[2] as a hypothesis possessed of a respectable degree of plausibility. With the realization of the fact of organic evolution, this hypothesis sprang to the forefront of importance, for it seemed to furnish a means of accounting for the evolution of consciousness in a series of gradations paralleling the gradations of material evolution. But, if consciousness has been evolved in this manner, then it must exist in some rudimentary and generalized form in every atom, and in a somewhat more specialized form in amoeba until, rising by successive stages of specialization, it finally attains the degree of complexity and self-awareness which we subjectively experience within ourselves. Now our waking consciousness is lost in profound sleep, or as a result of relatively trivial lesions in a very restricted area of the brain. Our organization is not rendered appreciably less intricate, and so, if intricate organism implies a parallel intricacy of consciousness, there must be a vast realm of consciousness of which we are normally unaware, *i. e.*, a "subconsciousness."

Now we must note the precise implication of this hypothesis, which is at first sight so simple and so plausible. The only consciousness of which we are ever normally aware is that minute fraction (as we must suppose it to be, if the above reasoning is correct) which constitutes our *waking* consciousness. To account for this, however, we are inventing a whole spectrum of states of consciousness, of which only a minute proportion is visible to us. In the physical spectrum there are certain gaps which have not as yet been rendered visible to us by the artificial senses of science, but the areas which have become visible form so large a proportion of the whole, and are so widely dispersed within it, that we are undoubtedly justified in assuming that the physical spectrum is truly continuous. But what would we say to the physicist who, having caught a glimpse of the sodium lines, were to straightway declare "From this I infer the existence of a continuous spectrum, from the infra-red to the x-rays?" This "reasoning," so obviously reckless in the physical world, has not infrequently been accepted as valid by biologists such as Driesch and Verworn and philosophers such as Bergson. Their unquestioning faith doubtless arises out of the difficulty of conceiving any other origin of waking consciousness *if we suppose that consciousness has been evolved*. But is this supposition really necessary?

[2] G. S. Brett: "A History of Psychology," London, 1912, Vol. 1, p. 32.

The alternative supposition to which the phenomena of "subconscious memory" might conduct us is simply this: *Memory is not always associated with consciousness of any kind, although it may occasionally be illuminated by consciousness.* Why, indeed, should we prefer the self-contradictory assumption of the existence of forms of consciousness which are not conscious, to the entirely self-consistent hypothesis of a purely unconscious mechanism of memory?

Memory is, in fact, no mysterious thing which is inexplicable in mechanistic terms. On the contrary, a twisted bar of steel may readily be shown, by the phenomena of hysteresis, to have "remembered" the torsion to which it has been subjected. Its behavior for long afterwards is modified by its "experience." I have elsewhere[3] proposed a theory of memory in animals which attributes this phenomenon to chemical changes in nerve fibrils which facilitate the subsequent passage of impulses along paths which have previously been traversed. The process of memory "trace-formation" would thus be essentially a process of autocatalysis, analogous to many other autocatalytic phenomena which occur among the activities of living organisms. Would it not be better, therefore, to place the more obvious interpretation upon the facts, and regard consciousness as a species of searchlight, illuminating a minute fraction of the vast void of blank unconsciousness in which our mechanisms move and have their being? This consciousness, which we may define as *the awareness of its content*, may illuminate at one moment a relatively large area of cerebral activity, at another a relatively small area. When it illuminates but a fringe of the horizon of our cerebral life, we are semi-awake or dreaming. When a larger arc is illuminated, we speak of full or "waking" consciousness. When the light descends, as under hypnosis, to the objects and events which lie near at hand, in the most intimate recesses of our cerebral life, then we momentarily view a panorama of events and memories of which the magnitude and variety amaze us, but of the existence of which we are normally oblivious.

A striking experiment, which reveals in the clearest fashion the mechanistic origin of memories and associations, has been performed by Professor I. P. Pawlow.[4] If a dog is shown food, its

[3] T. Brailsford Robertson: *Arch. Internat. de Physiol.*, 1908, VI, 388. "Folia Neurobiologica," 1913, VII, 309.

[4] These experiments have only been described in Russian, and the original descriptions are therefore inaccessible to me. I owe my knowledge of the above particulars to a personal statement and demonstration which Professor Pawlow very kindly gave to me during my visit to Petrograd in March, 1914.

salivary glands secrete saliva, the volume of which may be measured by inserting a tube in the duct of the gland and collecting the drips. If, at the same time that the dog is being fed, we apply some other stimulus, for example, pressure on the skin at some particular point, on repeating this many times over a period of several weeks the dog comes to associate this stimulus with the notion of food, and ultimately secretes saliva when the skin-pressure alone is applied. When the association has been thus established, pressure applied to any part of the skin yields a secretion of saliva. If, now, this stimulus is applied at intervals of half a minute several times in succession without the administration of food, so that the dog experiences a series of disappointments, the secretion of saliva progressively diminishes until it ultimately disappears. On now shifting the point of stimulation quickly to another area, a full secretion is obtained, but if we wait two or three minutes we find that it can not be elicited by the stimulation of that point either. A minute ago the dog possessed a memory associated with stimulation of this part of its skin. In the meanwhile nothing has been done. Yet the memory has lapsed. This loss of memory progresses from point to point over the whole skin, from the hind foot, up the leg, along the flank and down the front leg, arriving at each point a little later than it arrives at the preceding point. A change has occurred in the brain; a wave of forgetting has passed over the area of the brain which corresponds to the tactile sense in the skin, and the motion of this wave is so slow as to occupy several minutes. A few minutes later memory is restored, the effect of disappointment has worn off, and the wave of reawakened memory travels over the same path at approximately the same rate as the wave of forgetfulness. Now we can not suppose the dog to be conscious of all this. If the dog is really endowed with consciousness, which appears a reasonable supposition, then we must suppose that the consciousness of the dog is, in this case, merely a passive registrar of the memories which are formed and dissolved mechanically in its cerebral structures.

The difficulty attaching to a dualistic conception of the universe, which regards the possession of consciousness as some new thing, lodging in animate nature for the first time somewhere about the phylogenetic level of the vertebrates, is that it involves an apparent discontinuity of evolution. I think, however, that those who experience this difficulty are, after all, viewing the phenomena with a monistic bias. They are regarding consciousness as, in some sort, a "secretion of the brain," and, if it appears unheralded in nature, a breach of continuity in evolution is supposed to have occurred. Setting aside, for the moment, the ascertained fact that

organic evolution has actually occurred in a series of discontinuous progressions or "mutations," we may still say that if consciousness be regarded as a thing wholly distinct from matter, which is the point of view of the average layman, then no breach of continuity has occurred when the progress of organic evolution, approaching ever more nearly to the necessary degree of organization, at last intersects the reality of consciousness. To make the matter evident by a more or less imperfect analogy, no breach of continuity in the evolution of human implements occurred at the moment that the invention of the coherer enabled the Hertzian waves to be for the first time perceived by man. The complexity of our physical apparatus had then developed to the extent of intersecting these waves of great length, and henceforth, although without breach of continuity either in nature or in organic evolution, a new mode of perception was vouchsafed to man.

In recent years we have become accustomed to the idea of a space-time reality which, as the students of relativity have taught us, constitutes our physical universe. Now the consciousness-reality evidently intersects the space-time reality along the time-axis and nowhere else. It is extended in time, but not in space. I suggest that this intersection is accomplished by means of a specific cerebral apparatus which "perceives" absolute time. The nature of a machine capable of perceiving absolute time, as the eye perceives light, is not at all inconceivable, and its main characteristics have already been described by students of relativity.[5]

A time-machine would, by its very nature, add no energy to the organism in which it occurred, nor would it expend energy, for energy is invariably associated with mass. It would, however, be capable of influencing the *rate of release of energy*. In that case whatever happened would be a consequence of transformations of material energy, but the moment and rate at which it happened would be subject to influence by the state of consciousness. A signalman, in operating his switches, performs virtually no work, yet he determines out of a mechanically limited choice of possibilities the direction of discharge of all of the vast energy output of the railway engines. In similar fashion our consciousness may, within the mechanical limitations imposed by our cerebral architecture, direct the output of bodily energy, without generating or abstracting any energy itself. At the bifurcation of the paths the time-switch may be thrown this way or that, and, thereafter or before, all that happens is mechanically inevitable.

The cerebrum of man, thus viewed, contains a time-machine

[5] A. S. Eddington: "Space, Time and Gravitation," Cambridge, 1921, Chap. 2.

whereby our material entity intersects another reality, and the product of this intersection is consciousness. It is most important, in this connection, to realize that the coordinating activities of the brain do not necessarily involve consciousness. During sleep, or unconsciousness from other causes, bodily activities controlled by nervous agencies may continue uninterrupted. Many of these, for example, breathing, may be injected into the field of consciousness during waking hours, but this is not at all essential. The brain is a self-sufficing machine, with or without consciousness, that is, with or without activity of that latest addition to our cerebral apparatus which brings us into relation with the consciousness-reality through the medium of time.[6]

The sense of time thus becomes at once the most fundamental and the most remarkable of the endowments of man, for it lies at the very root and foundation of our consciousness. I am well aware that some attempts have been made to interpret the time-sense as a proprioceptive sensory perception of the rhythmic processes of the body, such as the heart-beat. It is obvious that such an explanation does not resolve the unique character of time-perception at all, for the receiving mechanism in the brain is presumed to interpret the rhythmic motions in terms of time. What need have we for a heart-clock when we must in any case have a brain-clock in order to interpret it?

This consideration leads us to an objection which has been invariably urged against the dualistic theories of consciousness, and that is the difficulty of conceiving interaction between such diverse things as an immaterial entity and matter. It is this difficulty which has led to the formation of the various views of psycho-physiological parallelism, whereby, for some reason not readily comprehensible, unless we accept the monistic interpretation of Spinoza, the phenomena of consciousness and those of material events march parallel with one another reproducing each other in every minutest respect. But now that we conceive time as one of the dimensions of a space-time entity, and assuming that this entity and the consciousness-entity intersect or coincide in the time-dimension, interaction becomes just as feasible and comprehensible as if they intersected in one of the space-dimensions. It is true that consciousness generates no energy, and therefore contributes nothing to the total energy-output of the body—but interaction without alteration of the output of energy is precisely what

[6] The importance of the time-sense in the evolution of man has latterly been especially emphasized by Korzybski ("The Manhood of Humanity," New York, 1921), but from quite a different point of view to that which has been adopted here.

we should expect if interaction is limited to the time-dimension, because rates and not masses would be the quantities affected. In the language of the chemist, consciousness might be expected to act as a catalysor, affecting only rates of transformation and not the final condition, save to the extent that alternative routes by which equilibrium may be attained may be decided by acceleration of one in preference to another.

It must not be forgotten, however, that this interaction is mutual, and that consciousness finds the receiving apparatus now in one state and again in another, due wholly to bodily events. It is important to realize that these are states or conditions of a machine which are merely registered by consciousness, and that consciousness no more generates the energy of the machine than the brain of the composer generates the electric current which operates an automatic piano. Thus the bodily events are not necessarily disturbed if the registrar of these is absent, as in dreamless sleep, or compelled to employ a grossly imperfect apparatus, as in the insane. Conversely, any interaction of consciousness in the catalytic manner of which the possibility has been indicated, will merely modify the channels or rates of discharge of energy, and the outcome will then be determined by the bodily machine. Hence, whatever their subjective counterpart may be to the individual who displays them, to an *external* observer all bodily activities will appear to originate wholly in the material machine itself, without any interference from consciousness. This does not mean that the existence of consciousness in an organism is necessarily impossible to demonstrate objectively, but it does imply that no act of any organism, conscious or otherwise, can be any other than that which is, under all the given circumstances, mechanistically inevitable.

I suggest that this hypothesis of "mechanistic animism" has a special claim to consideration because it reconciles our subjective experience with the mechanistic generalizations of the physiologist and the idealistic conceptions of reality. Moreover, the difficulty of conceiving the evolution of conscious from non-conscious entities is not encountered, for consciousness has not been evolved by organic nature—it has been discovered.

PASTEUR AND THE SCIENCE OF BIOLOGY[1]

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THE life and work of Louis Pasteur has had fundamental and far-reaching effects upon the direction and progress of the biological sciences. His influence may be traced along two paths—the one a direct road to specific developments such as the emergence and establishment of the science of bacteriology with its daughters, immunology and serology, and the concept of communicable diseases each due to a specific organism.

The other path of influence is less direct, but even more significant in that it turned the thought and effort of investigators in remoter fields into new lines of endeavor and thus shaped indirectly the course of scientific progress. Illustrations of such potent influence flowing from Pasteur to the contemporary and subsequent development of the biological sciences are seen in at least four directions, namely, in the origin of the science of animal parasitology and its relations to human and comparative pathology; in the effect of his disproof of the dogma of spontaneous generation upon the progress of evolutionary thought and the development of genetics; in the establishment of a demonstrated basis for the unity of the biological sciences and their close interrelation with the physical sciences; and in the significance of the experimental method to the biological sciences as a whole.

Thus, indirectly the method and results of Pasteur's work both stimulated and directed the course of development of the biological sciences in many fundamental respects. This was the result alike of his commanding genius and of the human relations of his discoveries along practical and philanthropic lines. His genius created the absolutely necessary scientific basis for his influence, and the applications of his talents to problems of human interest extended that influence far and wide and gave it power not only over specialists but over the minds of thoughtful men generally.

The science of parasitology in relation to disease owes its origin and progress in large part to Pasteur's work and influence, not

[1] Delivered at the Pasteur Centennial celebration at the University of California, February 1, 1923.

only by analogy to bacteriology, but directly. Prior to his successful attack upon the disease of silkworms parasitology was mainly a field for the investigation of the varied fauna of worms in the intestines of vertebrates, interesting to a few helminthological specialists. Pasteur's studies on fermentation and his successful attack upon the doctrine of spontaneous generation inspired him with the idea that communicable diseases were likewise due to germs. Not being a physician his access to these problems in man was for the time blocked. He therefore plunged with great zeal into the attack upon the diseases of the silkworm in the period between 1865 and 1870 and proved to the satisfaction of himself and his scientific friends that the destructive pebrine of the silkworm was an infective corpuscle of microscopic size found not only in the dying worm and sickly moths, but inherited in the eggs of infected moths by the next generation, and found also in some worms and moths showing at the time no signs of the disease. He saved the silk industry for France by this discovery and by his patient and persistent efforts to instruct the conservative French farmers in the practical methods of finding by microscopical examination stocks of moths free from the corpuscles of infection. He exposed ruthlessly the unscrupulous growers and vendors of infected stocks and finally succeeded in establishing standards of purity which saved this industry for his country, and thus paved the way for the prompt payment of the war indemnity of later years to Germany.

Pasteur did not know at the time that the corpuscle which he discovered was not a bacterium but an animal, a protozoan. His discovery was, however, made prior to our knowledge of the existence of those parasitic protozoans which produce disease in man and other animals. It was not until 1880 that Laveran found the malarial parasite in the blood of man; until 1891 that Councilman and Lafleur proved that amœba caused dysentery and liver abscess in man; and until 1902 that Dutton discovered trypanosomes in the blood of patients suffering from what was later proved to be the dread sleeping sickness of African natives and travellers. Pasteur's discovery opened the minds of men to the relations of parasitic organisms in general to disease and showed the possibility that some infections might be hereditary and persistent. He emphasized the parasitic aspect of the pebrine corpuscle, later known as the protozoan *Nosema bombycis*, and paved the way for the later expansion of human and comparative parasitology to its now ever-enlarging relations to pathology and disease.

The dogma of the spontaneous generation of living organisms from dead and decaying organic substances is as old and as per-

sistent as biological speculation. It is even quite impossible to say to-day that it is as yet quite dead. Many biologists even now harbor the hope that the progress of scientific discovery may some day enable man to describe in scientific terms and perhaps even to repeat the conditions experimentally under which the functions of life appear in matter and the simplest forms of life emerge from the non-living world. This process, however, when discovered, will be orderly and a part of the system of nature.

The ghost of spontaneous generation, which Pasteur and Tyndall so convincingly laid, was the belief and dogma supported at that time by reputable experimental biologists that it was possible to produce in dead and putrescent organic material in sealed glass tubes living organisms of known types. Life thus appeared to be derived from the dead material and the idea of the continuity of life was disenthroned. Pasteur proved beyond a shadow of a doubt that the experiments upon which the so-called proof of spontaneous generation rested were faulty in technique and that any organic substance once sterile and afterwards protected from the access of germs remained ever after sterile and free from living organisms of fermentation and decay, and of any kind whatever.

This proof was fundamental to Pasteur's new conception of the germ theory of communicable diseases, to Lister's aseptic surgery and underlies the success of the modern canning industry. It has had, however, far wider influences than these in the fields of biological thought and has determined the subsequent direction and rate of biological progress in no small degree. It proved conclusively the practical point that known forms of life can be produced only from preexistent organisms of the same kind. Not only do figs come from figs, but typhoid germs only from the typhoid bacillus. The firm establishment of this fact so soon after the publication of Darwin's "Origin of Species" rendered great service to the acceptance of the idea of organic evolution by establishing the fact of the orderly descent of organisms, the absolutely essential foundation stone for Darwin's contribution of the idea of descent with modification. At one stroke Pasteur not only unified the organic world, but prepared the way in men's minds for the idea of the unity of all vital processes. A by-product in our own day of this lifting of the incubus of a false dogma from the minds of men is seen in the rapid growth of the study of the mechanism of heredity and the birth of the science of genetics.

In another striking particular Pasteur's work is significant and will be, let us hope, increasingly prophetic for the mode of scientific progress in the future. I refer to the unification in his

attack upon research problems of scientific disciplines now so widely segregated and dispersed in separate compartments of organized science both in scientific education and in research. The rapid progress of science in the last fifty years has carried investigation and investigators into widely divergent compartments, walled off from each other by professional, bibliographical and departmental barriers that effectually prevent interchange of ideas and methods and offer, one might almost dare to say, the most impassable barrier to successful scientific discovery in our university life to-day—hence the growing tendency to establish research institutes where the disciplines separated in the university are united in attack upon common problems.

Pasteur's investigations ranged through nearly the whole gamut of our categories of the physical and natural sciences. He was a chemist, crystallographer, physicist, bacteriologist, mycologist, entomologist, parasitologist, protozoologist, and above and over all an experimental biologist. His life is an example to us all in these days of specialization. We can not turn back the hands of the clock of science to those days of Pasteur's early work when the sciences were simpler and rudimentary, but his results should teach us the value of synthesis as over against specialization and impress upon us the necessity of breadth of preparation in all sciences for effective work in any one of them. Above all, does it teach us the unity of all science and the great value and stimulus which may be derived from their close interrelation in instruction and research. Take, for instance, the first scientific problem attacked by Pasteur, that of the symmetry of crystals. It is fundamentally a problem of the organization of matter and extends from spiral nebulæ in the milky way through crystals to the living world, to the twisted trunk of the fox-tail pine and the left-handed child.

We owe to Pasteur the enthronement of the experimental method in the biological sciences. Without it biology is at the mercy of hypothesis. Pasteur, next to his hatred of falsehood and greed, dreaded nothing more than the possibility that he might be led to conclude that something might be true because he desired it to be true. Scientific prejudice, if this incompatible juxtaposition of words may for the moment be permitted, was Pasteur's *bête noir,* and the experimental method was his salvation. His skillful, simple and convincing use of the method has for all time made it an indispensable weapon in the armament of all of the biological sciences whose assaults every hypothesis must ultimately withstand before recognition can be granted.

Pasteur's life and labors were dominated supremely by loy-

alties, to his parents, to his home, his wife and children, to his teachers, pupils and colleagues, to his country and to his faith and to science. Loyalty was his dominating passion. Service to his fatherland led him to take up so-called practical problems, silkworm disease, the ailments of wines and beers, the dreaded anthrax of the herds of the French farmer, and typhoid and rabies. This breadth and strength of his loyalties carried him successfully past the Scylla of shortcut and futile methods which lesser men sometimes attempt in the applied sciences and the Charybdis of dehumanized scientific abstraction to which some great minds limit their scientific endeavors and sympathies. For him the truth could be found in both fields of scientific endeavor, the pure and the applied, but his sole aim and goal was invariably the truth, and his method of attack the same in all cases.

Investigators and students in the biological fields will find much to admire and much to learn in Pasteur's methods of work. These were always characterized by the two elements which Poincare has so emphasized in his essay on "The Method of Mathematical Discovery," namely, intensive application to all the details of the problem by direct and repeated examination until his whole being, conscious and subconscious, was absorbed in its contemplation, and secondly the discursive excursions of his creative imagination until the disjunct, diverse and incoherent data began to be assembled in order, and the emerging relations excited those esthetic satisfactions of the intellect which presage discovery. To these two steps Pasteur always added a third, the rigid test, by experiment, of the truth or falsity of every emerging discovery at every vulnerable point, until logic and reason alike approved the conclusion.

To one who reads between the lines of Pasteur's varied and so often successful methods of attack upon difficult problems and finds the ever-recurrent challenge to himself and his colleagues, "Let us all work," one is impressed in it all by his belief in his ultimate success. To him the world was neither chaos nor chance but infinite order and the expression of The Infinite.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By Dr. Edwin E. Slosson
Science Service, Washington

THE ECLIPSE AND EINSTEIN

The development of a batch of photographic plates is often awaited with impatience and anxiety. In the case of an amateur the impatience is manifested by the snapshotters and the anxiety by his sitters.

But perhaps never before have so many people in all parts of the world been eager to learn "how the plates turned out" as in the case of those brought back from Australia by Dr. W. W. Campbell, the man who observes the movements of the heavenly bodies by night at the Lick Observatory and by day controls the movements of the students at the University of California.

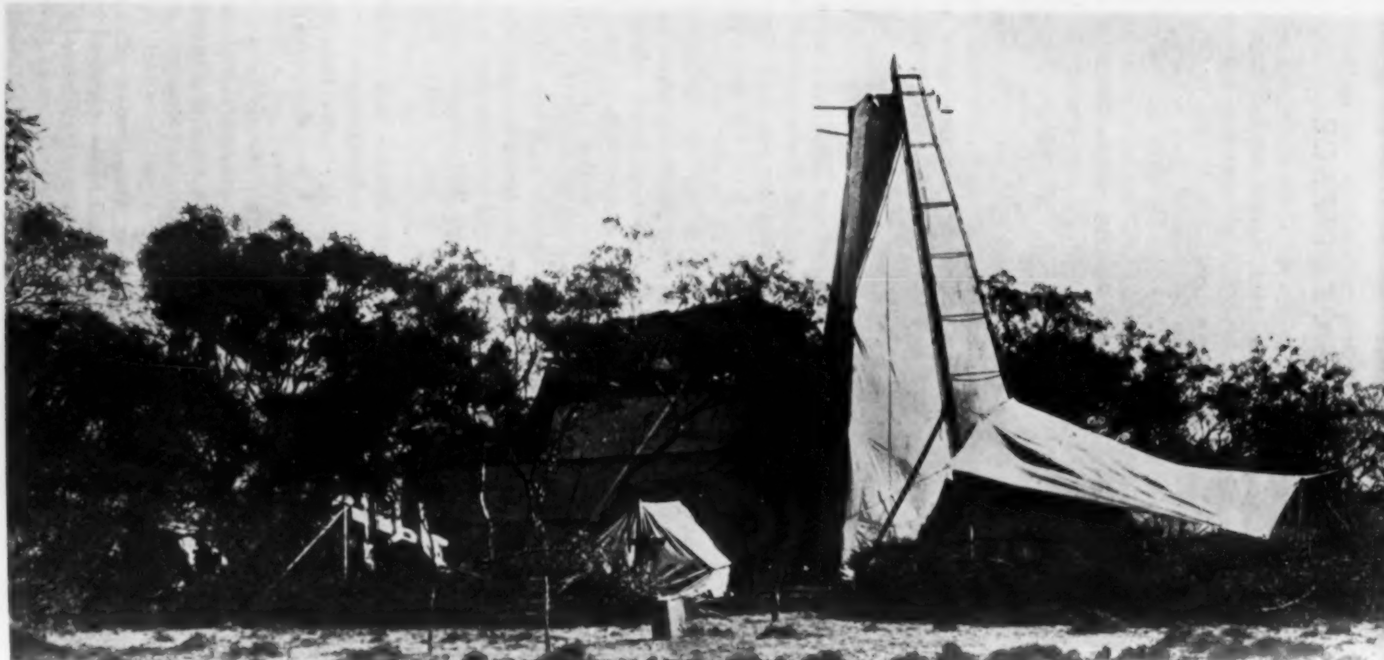
For these negatives taken during the eclipse of September 21 contained the evidence for or against the Einstein theory of relativity which has excited the interest of all astronomers and, for various reasons, an unexpectedly large proportion of the public. The less people understood it the more eager they were to hear about it.

The man who manifested the least anxiety about the results of the eclipse expedition was apparently Einstein himself, for having made up his mind eight years ago how the heavenly bodies must behave he remains serenely indifferent to the efforts of astronomers to find out how they do behave. It followed as a logical deduction from his theory of the relativity of all measurements in space and time that a ray of light passing close to the sun would be drawn out of its straight course as though the light were attracted by the pressure of such a heavy mass. And since the path of the ray is drawn inward toward the sun an observer on the earth looking back up the ray would see the star as though it were moved outward from the sun. If a photograph of a group of stars taken with the sun in the middle is compared with a photograph of the same group without the sun, the images of the stars in the former case will seem to have been displaced from their ordinary positions in the sky. The stars nearest the sun's disk will naturally seem to have moved out the most. The effect is the same as you have noticed when a patron of the bootleggers gets aboard a crowded street car. All move away from him and those nearest the obnoxious individual move farthest.

Nobody had discovered or suspected such a displacement of star images about the sun until Einstein predicted it from his mathematical theory. As figured out from his formula, a ray of starlight just grazing the sun's disk would be deflected toward the sunny side to the extent of 1.75 seconds of arc. The star images further away would be displaced less according to their apparent distance from the sun.

Of course, the stars can not be photographed when the sun is shining into the telescope, so one must wait till the sun is totally shielded from the earth by the moon. The British astronomers took advantage of the first opportunity to put the Einstein theory to the test, the eclipse of 1919, and they came back from South America and Africa with the report that the star images were dispersed as Einstein had predicted. But they had good photographs of only seven stars and have been sharply criticized in scientific circles.

But now that President Campbell has explained to the American Philosophical Society of Philadelphia and the National Academy of Sciences at Washington the results of his observations in Australia there is little



Wide World Photo

THE CROCKER ECLIPSE EXPEDITION

Temporary observatory at Wallal, South Australia, at which the expedition from the Lick Observatory under Professor W. W. Campbell made photographs confirming the Einstein prediction of the deflection of light by gravity and obtained other important results.

THE SOLAR CORONA
Photograph taken by the Crocker Eclipse Expedition at Wallal.

ground left for skepticism on this point. Instead of seven stars, he has five sets of plates containing from sixty-two to eighty-four star images and when these are measured with the micrometer and calculated to a common position at the edge of the sun the mean is 1.74 seconds of arc, which is almost exactly the deflection predicted by Einstein. The negatives are 17 inches square, and it took Dr. Campbell fifty hours of working time to measure up the stars on a single eclipse plate in comparison with one of the same section of the sky at other times.

The same plates were measured by different astronomers who could not know what the results would be until they were finally figured out. Check plates taken of other stars show that the displacement images can not be due to any defects of the telescope or sensitive plates. The Canadian eclipse expedition also obtained observations confirming the Einstein theory.

So certain does Dr. Campbell feel of these conclusions that the Lick Observatory will not devote further effort to the verification of the Einstein theory, although the next eclipse comes in California on September 10. The British astronomers had previously announced that they would not send out an expedition to observe the coming eclipse if the results of the Lick expedition to Australia last year settled the matter satisfactorily. This it seems to have done, but there are enough other unsettled problems in the relativity theory to keep the scientists busy for many years.

M. EDOUARD BAILLAUD
Director of the Observatory of Paris, on whom the Bruce Gold Medal of the Astronomical Society of the Pacific has been conferred through the American Ambassador at Paris.

COAL OIL FROM COAL

When kerosene first came into use as a lamp illuminant it was called "coal oil," for it used to be supposed that petroleum had somehow been formed from coal. Later that theory was called in question and geologists are still disputing the origin of oil. We seem likely to use it up before we find out where it came from. But even if coal oil turns out to have been an inappropriate name in the past, it may prove to be true in the future. For petroleum can be made from coal and some day we may have to make it that way.

For the less oil we have the more we use. The lower the supply in the ground the higher the output of our refineries. The report of the Bureau of Mines for January comes to my table to-day and I find that twenty million gallons of gasoline were turned out every day on the average, while for the same month in 1922 the output was fourteen million gallons. This increase can not keep up forever, however liberally you may estimate our unseen supply underground.

The countries that are short of petroleum are already contriving substitutes. The Germans, who were well supplied with coal, but had little oil, began before the war experimenting on methods of making artificial petroleum. Since they have lost some of their best coal fields through the war and oil is harder to get than ever, they have been still more active in such research, and it is rumored by returned travelers that they have been more successful in that quest than has appeared in print. What little has leaked out has mostly come through the patents which Freidrich Bergius has taken out in Germany and the United States from 1914 to 1922. But a patent, especially a German patent, is by no means so "patent" as it is supposed to be, so not much is known by the outside world about the details or the practicability of the process.

Theoretically it is simple enough. Petroleum is a mixture of compounds of hydrogen and carbon. Just hitch up these two elements and there you are!

But there are other hitches in the proceedings. Either carbon or hydrogen will unite readily with oxygen, but they have little liking for each other. Only when stirred up by high heat and forced into contact by high pressure will they combine. Besides the expense of the process there is the expense of the materials. Carbon is cheap and abundant enough in the form of coal, but hydrogen has to be obtained by tearing it away from the oxygen with which it is combined in water. This may be done by passing steam over red hot iron turnings which pick up the oxygen and release the hydrogen. Or steam may be passed through beds of hot coal which give what is known as "water gas," a mixture of hydrogen and carbon monoxide, both good combustibles.

In making synthetic petroleum it appears that the coal is first powdered and mixed with heavy oils. This pasty mess is put into a tight steel retort and a current of hydrogen or water gas is run through the vessel at a temperature of some 700 degrees Fahrenheit and a pressure of a hundred atmospheres.

Under these conditions the carbon and the hydrogen gas unite in all sorts of ways and form liquid products, and an oil much like natural petroleum distills off from the retort. This is redistilled; the lighter fractions collected as gasoline, kerosene, benzene and the like, and the heavy residue returned to the retort and mixed with the next batch of coal.

It is claimed that by such a process as high as 87 per cent. of the carbon in the coal can be converted into liquid hydrocarbons, such as are found in natural petroleum and also the coal-tar products which can be used as material for

dyes and drugs, preservatives and perfumes. The nitrogen in the coal, which is lost in ordinary combustion, is here obtained in the valuable form of ammonia.

The coal for this process does not have to be of a special quality as is required in making gas or coke by our present methods. Any kind or form of coal can be used and high yields of the hydrogenated products are said to be obtained from the brown coal and lignite of which Germany has an abundance. Peat may be thus worked up into gasoline and other marketable compounds, also pitch, tar, sawdust and any vegetable material.

BOARD OF VISITORS TO THE BUREAU OF STANDARDS

Left to right—front row—Ambrose Swasey, of Cleveland, Ohio; F. W. McNair, president of the Michigan School of Mines; Samuel W. Stratton, formerly director of the Bureau of Standards and now president of the Massachusetts Institute of Technology. Back row—John R. Freeman, of Providence, and Wilder D. Bancroft, professor of physical chemistry at Cornell University.

Although there is little likelihood at present that such a complicated process will come into use here so long as our oil wells continue to flow, it is reassuring to know that when they do run out we shall not be altogether deprived of the efficient fuel that has made the auto, the airplane and the motor boat possible. We should not know how to get along without the paraffin, vaseline, lubricating oil and innumerable other petroleum products that enter into our daily life. Mineral oil contains so many such valuable substances that it is a pity to burn it up in running steam engines where other fuels may serve. As petroleum gets scarcer, we may expect to see the burning of the crude oil prohibited.

HOW OLD IS DISEASE ?

THERE is a curious belief still lingering in the popular mind that diseases came in with civilization; that primitive men and animals lived in a state of perpetual health and died a natural death—though it is hard to see what is meant by "natural" in this sense. Even Mrs. Charlotte Perkins Gilman, who is very much of a modernist, falls into this folk fallacy, for in her poem on "the little Eohippus" she makes the cave-man prophesy:

> We are going to wear great piles of stuff
> Outside our proper skins!
> We are going to have diseases!
> And accomplishments! ! and sins! ! !

"It was a clinching argument to the Neolithic mind," but really it was not so. The Neolithic man was all too familiar with diseases and doubtless had also his accomplishments and sins. He suffered from rheumatism and "cave gout" and toothache, for caverns are damp and chilly lodgings. He shared the diseases as he did the lodgings of the cave bear and saber-toothed cats. The earliest human bones, if indeed they can be called human—those of the ape-man who lived in Java some half million years ago, bears the marks of a painful malady. The skull of the Dawn Man of Piltdown, England, a hundred thousand years old, is deformed by disease.

The men of the Stone Age must have suffered frightfully from headache for they allowed the tribal doctor to cut holes in their skulls with flint knives to let out the demon that was causing the pain. And if the patient was not cured or killed by this treatment he sometimes tried it again when he had another headache. Dr. Roy L. Moodie, of the University of Chicago, in his new book, "The Antiquity of Disease," says: "A few ancient skulls reveal five cruel operations, which had all healed. The patient had survived them all." But he suggests that since this custom of trepanning was practiced most commonly in Peru the patient may have had the relief of a local anesthetic in the form of a few leaves of coca, the plant that gives us cocaine.

But eons before the human era the dumb animals had to endure all manner of diseases. The dinosaurs of the Mesozoic Era had "misery in the bones"—and such bones as they were! You have seen them in the museum. It must have been worse than a giraffe's sore throat. "Pott's disease" was doing its wicked work millions of years before Dr. Pott was born, though this sounds like an anachronism. This is shown by the discovery of backbones of saurians that had been stiffened by tuberculosis. Tumors are to be seen on reptile skeletons buried in the rock chalk of Kansas, and broken bones showing signs of bacterial infection have been found as far back as the Permian of Texas.

Geologists have to depend mostly upon bones for their knowledge of ancient diseases since the softer parts do not leave fossil remains, but the stems of crinoids in the coal fields are found bored into by worms and it is apparent that the mollusks,

crustaceans and plants of earlier ages were afflicted with parasites and other pests.

The earliest and simplest forms of plant and animal life, the bacteria and protozoa, seem envious of later arrivals and wage perpetual war on them to this day. The larger animals prey upon the smaller, but so do the smaller upon the larger, and the most dangerous of beasts of prey are the littlest. When man appeared on the planet he found the microbe lying in wait for him. Sooner or later, we all fall victims to the lower forms of life, and, after death, if not before, become the food of our invisible enemies. Even Tut-Ankh-Amen, embalmed and entombed for the perpetual preservation of his personality, will ultimately be gathered into the recurrent cycles of common life.

SCIENTIFIC ITEMS

We record with regret the death of Arthur Gordon Webster, for more than thirty years professor of physics in Clark University; of Schuyler Skaats Wheeler, president of the Crocker-Wheeler Company of New York, distinguished as an electrical engineer; of John Venn, president of Caius College, Cambridge, eminent for his work on logic and later for his archeological researches, and of Charles Emmanuel Forsyth Major, the English paleontologist.

At the meeting of the National Academy of Sciences held in Washington on April 25, Dr. A. A. Michelson, professor of physics in the University of Chicago, was elected president in succession to Dr. Charles D. Walcott, secretary of the Smithsonian Institution. Dr. J. C. Merriam, president of the Carnegie Institution of Washington, was elected vice-president in succession to Dr. Michelson.

Sir David Bruce has been nominated by the council as president of the British Association for the Advancement of Science at its meeting next year in Toronto.

EVOLUTION AND THE SCHOOL

as seen by the *Dallas Morning News for April 17, 1923, before the meeting of the Fundamentalist Conference at Fort Worth, Texas.*

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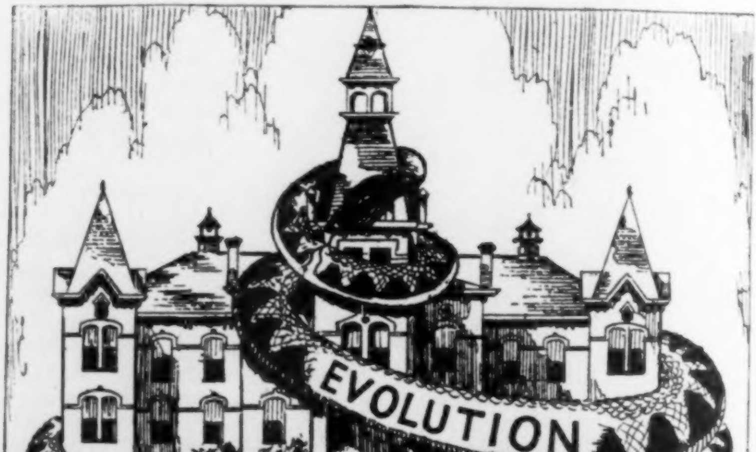

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